DEMAND, SUPPLY AND PRICE OF HARDWOOD LUMBER: AN ECONOMETRIC STUDY

by

William G. Luppold

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in partial fulfillment of the requirements for the degree of

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in

Agricultural Economics

APPROVED:

Joseph Havlicek, Jr.

Leonard Shabman

Harold Wisdom

Eugene Wendt

Ernest Bentley

February, 1981

Blacksburg, Virginia
ACKNOWLEDGEMENTS

This dissertation represents the efforts of many individuals other than myself. The most prominent of these other individuals is my major professor Joseph Havlicek Jr., who I most wisely chose to study under. Much appreciation must also be extended Harold Wisdom, , Eugene Wengert, , and a multitude of people in the furniture and hardwood lumber industries for helping me understand the physical aspects of the hardwood lumber market.

I'm also grateful to the U. S. Forest Service for allowing me the privilege to explore this rather unique market. In this regard much gratitude must be extended to for his acceptance and understanding of the tardiness of this research. and must be commended for reading through the rather boring drafts of this dissertation. Also in this regard, gratitude must be extended towards , my soon to be wife, for reading through the multitude of rough drafts of this work.

Deep gratitude must also be extended to Virginia Tech and its excellent computer facilities. In this respect thanks go to who single handedly lead our department into the 21 century world of word processing. Thanks also must be extended to and for their patience in showing me the ropes of the word processing facilities.

In concluding an unmeasurable amount of gratitude is extended to my
parents. To my father who taught me the mechanics of life and some of the art of living; all I can say is I'm extremely lucky. To my late mother, who this dissertation is dedicated to; all I can hope is that all the faith she had in me has shown itself in this work.
In Memory of my Mother
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CHAPTER I
INTRODUCTION

The deciduous, or hardwood, forests of the eastern United States are a resource of substantial value. A variety of industrial inputs and consumer goods is produced from material derived from these hardwood resources. During the last 30 years, about 50 percent of the hardwood roundwood harvested was used as pulpwood or fuel while 33 percent was used in the production of hardwood lumber.\(^1\) Hardwood veneer production has historically accounted for only 3 percent of the hardwood roundwood used, while the remainder was consumed in the production of miscellaneous products.\(^2\)

The Resource Planning Act of 1976 requires the United States Forest Service to develop long-range plans that will provide adequate future supplies of sawtimber and subsequent wood products from public lands. A basic ingredient for long-run planning is economic information on the various lumber, veneer and wood products markets. Schuler (26,27) and others are developing such information for the pallet, particleboard, hardboard and hardwood plywood markets. The current study focuses on developing economic information for the hardwood lumber market.

Production of hardwood lumber approached one billion dollars in 1977.\(^3\) Also in 1977 pallets and containers accounted for approximately 35 percent of the hardwood lumber used while furniture and fixture production accounted for 29 percent.\(^4\) Rail-tie production accounted for 10 percent of the hardwood lumber used while the remainder of the
hardwood lumber was used in the production of laminated decking, hardwood flooring and miscellaneous uses.⁵ According to the United States Forest Service projections, the use of hardwood lumber in the year 2000 will be at least 57 percent higher than the 1978 level and could be as much as 81 percent higher.⁶

THE PROBLEM

The hardwood lumber market has traditionally exhibited mild fluctuations in prices and quantities produced (Table 1). However, during the mid and late 1970's, industrial users of hardwood lumber have become concerned over high lumber prices and current and future availability of this commodity.

Industrial users' concern over hardwood lumber price stem from the fact that lumber graded No. 1 Common and Better of some species normally used by furniture manufacturers has almost tripled in price between 1970 and 1978 (Table 2). These price increases are most apparent for red and white oak, Appalachian tough ash and black cherry lumber; the prices of No. 1 Common Appalachian soft maple, yellow poplar and southern tupelo have followed the general rate of inflation. Prices of No. 2 Common lumber and lower also tended to increase with the price of No. 1 Common lumber. The price differentials exhibited in Table 3 indicate that the price spreads between No. 1 Common and No 2 Common Appalachian red oak, tough ash and black cherry lumber have increased considerably while the differentials for Appalachian soft maple, yellow poplar and southern tupelo have increased by a lesser extent.
Table 1  Hardwood Lumber Production, Demand, Price, Inventories and Exports for the United States, 1960-1978

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<th>Year</th>
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<th>Quantity Demanded (million bf)</th>
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a) Source: U. S. Department of Commerce, Lumber Production and Mill Stocks, Current Industrial Reports

b) Quantity demanded was determined by adding current quantity supplied to inventories lagged one year and subtracting current inventories and current exports.

c) Source: U. S. Department of Commerce, Statistical Abstracts of the United States

d) Source: U. S. Department of Commerce, United States Exports by Commodity by Country, Federal Trade Report 410 (includes rough and dressed domestically produced lumber, does not include rail ties, dimension and flooring)
Table 2  Price of No. 1 Common Oak, Ash, Cherry, Maple, Poplar and Tupelo in the United States, 1960-1978, (in dollars per thousand bf)

<table>
<thead>
<tr>
<th>Year</th>
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<th>Ash b/</th>
<th>Cherry c/</th>
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Source: Hardwood Market Report

a) Appalachian red oak plain 4/4"
b) Appalachian tough ash 4/4"
c) Appalachian cherry 4/4"
d) Appalachian soft maple 4/4"
e) Southern poplar plain 4/4"
f) Southern tupelo plain 4/4"
<table>
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Source: Hardwood Market Report

a) Appalachian red oak plain 4/4"
b) Appalachian tough ash 4/4"
c) Appalachian cherry 4/4"
d) Appalachian soft maple 4/4"
e) Southern poplar 4/4"
f) Southern tupelo 4/4"
The increase in the price of the higher grades of oak, ash and cherry lumber may have been caused by increased domestic and foreign demands for these species while quantity supplied remained relatively constant. The increase in demand has made it difficult for some furniture manufacturers to obtain higher grade oak, ash and cherry lumber.

A factor affecting future domestic availability of hardwood lumber is the increase in foreign demand for hardwood lumber. The increased export demand that occurred during the 1970's was almost entirely for higher grade lumber. This increase has probably been spurred by the decreasing value of the U.S. dollar against European and Japanese currencies.

Another factor affecting future availability of hardwood lumber is future supplies of quality sawtimber. Much of the larger size timber remaining, which is suitable for higher quality lumber and veneer production, exists in small groups or as single trees and, therefore, can not be economically harvested at current price levels. Furthermore, much of the hardwood timber in the East is on small private tracts that are used for homesites and other purposes that are often viewed by the landowner as incompatible with timber harvesting.

Current and future behavior of the hardwood lumber market will affect Virginia and Virginians because wood furniture and hardwood lumber manufacturing are major industries in this state. In 1977 the wood furniture industry in Virginia employed over 18 thousand persons who earned over 136 million dollars. In fact, in 1977 Virginia was the
nation's second largest wood furniture manufacturer, producing 13 percent of the total United States output, by value of shipment.\textsuperscript{11} Furthermore, Virginia consumed only 2.5 percent of the case-goods and tables sold in 1977.\textsuperscript{12} Therefore, Virginia is a major exporter of wood furniture.

Virginia was the third largest domestic producer of hardwood lumber in 1978 accounting for nearly 7 percent of the national production.\textsuperscript{13} Furthermore, Virginia ranked second only to West Virginia in volume of select white and red oak sawtimber.\textsuperscript{14} Select red and white oak accounted for 23 percent of the wood used in domestic furniture production in 1978.\textsuperscript{15} These species represent nearly 50 percent of the hardwood lumber exported during the 1970's.\textsuperscript{16}

Currently, little information is available concerning the economic structure of the hardwood lumber market. The lack of economic information concerning this industry hampers market coordination and increases the degree of uncertainty of future market conditions facing demanders and suppliers of hardwood lumber. \textsuperscript{17} Under conditions of uncertainty, optimal resource allocation does not occur, thus reducing the level of profit that individual demanding and supplying firms can obtain.

Information about the reaction of hardwood lumber demanders to changes in hardwood lumber price and other important factors could reduce the degree of uncertainty faced by hardwood lumber demanders and suppliers. With this information suppliers will be in a better position to anticipate changes in hardwood lumber demand, thus allowing these
suppliers to make better (more profitable) decisions. Likewise hardwood lumber demanders could make better decisions if they had information concerning the reactions of lumber suppliers to changes in lumber price and other important factors that influence supply. Since hardwood lumber demanders and suppliers can allocate their resources more efficiently, relative prices of products produced from hardwood lumber may also decrease. Finally, information on the structure of the hardwood lumber market is a necessary ingredient for the development of long-range plans to ensure adequate future supplies of hardwood sawtimber from both public and private lands.

OBJECTIVES

A) To identify the major factors affecting the aggregate demand, supply and price of hardwood lumber; and to estimate the impact of changes in these factors on lumber production, usage and price.

B) To identify the major factors affecting the demands of wood furniture producers for oak, maple, poplar, open grained and closed grained lumbers; and to estimate the impact of changes in these factors.17

C) To evaluate the predictive ability of the estimated equations; and to predict the levels of quantity supplied, quantity demanded, price and inventories of hardwood lumber in the year 2005 under four select sets of scenarios.
ORGANIZATION OF DISSERTATION

The hardwood lumber market will be described in Chapter II. The information presented in Chapter II will be incorporated into the model development presented in Chapter III. The estimated results for the aggregate relationships, stipulated by Objective A, will be presented in Chapter IV. The estimated results for furniture manufacturers' demands for different lumber, Objective B, will be presented in Chapter V. Projections for the year 2005, Objective C, will be presented in Chapter VI. Chapter VII will be a presentation of the summary and conclusions of the study.
FOOTNOTES


2 Ibid., p. 1.


4 Percentage of wood used by furniture manufacturers was calculated by dividing lumber use by furniture manufacturers by total quantity of hardwood lumber demanded. Total wood use in furniture manufacturing was derived by summing wood use by household wood furniture, household upholstered furniture, office wood furniture, public building furniture, kitchen cabinet and wood TV radio manufacturers plus millwork. Source: U.S. Department of Commerce, household furniture, office, public building and miscellaneous fixture, office and store fixture and millwork, plywood and structural wood members, 1977 Census of Manufacturers Industrial Series, Washington D.C., July 1980.

Percentage of wood used by pallet manufacturers was calculated by dividing wood used by pallet manufacturers by total wood used. Wood used by pallet manufacturers is calculated by multiplying total number of pallets produced by 22 to find the total bd. ft. wood used by pallet producers. This figure was multiplied by a factor of .66 to find the amount of hardwood used in pallet production. This hardwood figure was then multiplied by .66 to account for the amount of lumber used as opposed to whole logs. Information on pallet production was obtained from the National Wooden Pallet and Container Association, Annual Report Washington D.C., 1977, the source for the conversion figures Walt Wallin, U.S. Forest Sciences Lab., Princeton, W. Va.

5 Percentage of wood used by rail-tie producer was calculated by dividing lumber use by rail-tie producers by total quantity of lumber demanded. Lumber use by rail-tie producers was derived from U. S. Department of Commerce, Sawmills and Planing Mills, 1977 Census of Manufacturers Industrial Series, Washington D.C., July 1980, pp. 24A-16.


7 The increase in foreign quantity demanded of high quality oak and ash lumber is exhibited by the figures in Federal Trade Report 410. Conversations with lumber brokers also indicate an increased demand for cherry lumber. Increase in domestic demand for the open grain lumbers is exhibited by the large showings of open grain furniture at the various marts during the 1970's. A comparison of the production of
these species in 1971 and 1978 as published in Current Industrial Reports suggest a steady supply of lumber of these species. It is appropriate to consider these two years because aggregate supplies were nearly the same.

8 Hair, D., "Hardwood Market Outlook", 1977 John S. Wright Forest Conference, Purdue University, Department of Forestry, West Lafayette Ind., 1977, p. 21.

9 Ibid. p. 21.


17 Open grained lumbers include oak, ash, elm, pecan, hackberry and other lumbers wide grained structures. Closed grained lumbers include maple, cherry, mahagony, beech, gum and other lumber with a tight grain structure.
CHAPTER II
THE HARDWOOD LUMBER INDUSTRY

The purpose of this chapter is to briefly outline some of the major characteristics of the hardwood lumber market from the tree standing in the forest to the finished product. The emphasis in this chapter is on the market for No. 1 Common and Better lumber. Since the major users of No. 1 Common lumber are domestic furniture manufacturers, an effort will be made to describe how these manufacturers acquire and use hardwood lumber.

THE PRODUCTION SIDE

The vast majority (71 percent) of commercial hardwood forest land is owned in small tracts by private land owners. These lands are usually termed nonindustrial private forests (NIPFs). Sixteen percent of commercial hardwood forest land is owned by public agencies, while industrial ownership accounts for the remaining 13 percent.

The majority of commercial hardwood forest land is on NIPFs, and much of this forest land is unmanaged, although not necessarily mismanaged. Poor silvicultural practices and low productivity on NIPFs are commonly attributed to either a lack of owner understanding of the potential of their forest land or economic barriers such as diseconomies of scale, low rates of return, lack of markets, and short planning horizons.

Stumpage is purchased by logging contractors, lumber producers
(sawmills) and sometimes by furniture manufacturers. Most small or portable sawmill operations that purchase stumpage transport their saw to or near the stumpage site. Larger sawmills may purchase stumpage and employ their own harvesting crew or hire a logging contractor to harvest the stumpage. Stumpage purchased by logging contractors is usually cut by the contractor who, in turn, sells the logs to a lumber mill. Since some sawmill operations are vertically integrated and purchase or own stumpage, while other firms purchase logs, it is difficult to separate aggregate demand for stumpage and the aggregate demand for logs. Furthermore, there are an undetermined number of mills that use a combination of these roundwood procurement methods.

Logs are delivered to the mill log yard where they are sorted by species. During this separation procedure, veneer logs are usually placed apart from other logs, and sawlogs are separated from lower quality and small diameter logs. Lower quality and small diameter logs, as well as sawlogs of lower-value species that are usually scarce in the area around the sawmills, are placed in a pile that is termed mixed hardwoods. These lower-value logs and sawlogs may be cut into lumber or chipped up and made into some other wood product. After the logs have been sawn, the resulting lumber is separated by thickness and usually graded. Higher-grade lumber is demanded by wood furniture producers and cabinet makers both domestically and abroad, while most lower grade lumber and mixed hardwoods are demanded by pallet producers and upholstered furniture manufacturers. Large cants, or log centers, are often sold to rail-tie manufacturers.
The markets for higher grade and lower grade hardwood lumber can be separated by physical differences in product and differences in end uses, but the production of lower grade lumber is usually a by-product of higher grade lumber production. This occurs because the price of lower grade lumber is considerably less than the price of higher grade lumber thus, most sawmills make their largest profit on high-grade lumber production. However, there are pallet manufacturers that use No. 1 Common and Better lumber for pallet production.

The amount of No. 1 Common and Better lumber used by pallet manufacturers is not known. Some large pallet sawmills run two saw lines—one for higher grade logs and one for lower grade logs. The lumber from the higher grade logs is separated by grades while the lumber from lower grade logs goes directly into pallets. There are also pallet mills that use 100 percent of their sawn lumber in pallet production. Although some pallet mills of the latter type may cut some high grade logs and subsequently use high grade lumber in pallets, it is doubtful that much high grade lumber of preferred species (select oaks, ash, cherry, etc) ends up in pallets since the sawlogs and lumber of these species command a relatively high price. However, high grade lumber of species that are less desirable in furniture manufacturing may be used in a significant volume by pallet producers.

THE CONSUMPTION SIDE

Higher grade hardwood lumber is usually purchased green, although some is kiln dried at the sawmill. Green lumber may be purchased
directly by furniture manufacturers, or purchased by lumber wholesalers who in turn sells lumber to domestic and foreign lumber buyers. Lumber wholesalers perform market services such as grading lumber by National Hardwood Association standards, separating longer lengths, from shorter lengths and kiln drying lumber. Lumber wholesalers usually sell the highest quality lumber to foreign purchasers and sell the remainder (mostly grade No. 1 Common) to domestic furniture producers.

Some furniture manufacturers buy green lumber from what is termed a captive sawmill. These sawmills may be owned by the furniture producing firm or have a verbal or written contract to sell all the higher grade lumber produced by the mill to the firm. Although these mills do not always receive top dollar for their lumber during periods of strong demand, they are insured of a buyer during periods of low demand.

Once lumber is received at the furniture manufacturer's lumber yard, it is usually graded, stacked and allowed to air dry. After the lumber has been air dried, it is placed into a kiln where it is dried to 6 to 8 percent moisture level. Kiln dried lumber is usually placed into dry storage for a short time before it is used in the manufacturing process. The amount of time that lapses between receiving green lumber and cutting kiln dried lumber may be 6 weeks to 6 months, depending on business conditions and managerial practices.

Larger furniture manufacturers tend to purchase lumber of many different species. These firms usually sell several different lines of furniture in different price ranges. The firm tends to decrease the use
of higher price species in lower priced furniture by using less expensive species for exposed surfaces. These firms also use less expensive woods such as yellow-poplar for interior, core and banding parts. However, small manufacturers often sell only one to three lines of furniture and tend to purchase only one species of lumber for each line, along with the interior or core species. There are also furniture manufacturers who specialize in lower price or promotional furniture. These manufacturers demand very little lumber of the higher price species.

Since larger furniture manufacturers use several species of lumber and produce several different lines of furniture, they are in a better position to substitute lumber of different species in response to changes in lumber prices. If a firm can manufacture oak furniture more profitably than maple furniture, that firm may attempt to push oak furniture at the furniture marts and to their dealers or representatives. Large manufacturers are in a better position to substitute one species since they can afford to offer several lines of furniture at the marts, while smaller producers usually abide by a more conservative approach of showing what has sold in the past or a variation thereof.

Wood and other kinds of furniture are displayed to potential buyers at furniture marts. Furniture samples are placed on exhibition at these marts and furniture buyers place orders after viewing these displays. If a sufficient number of orders for a particular piece or suite are placed at and after the mart, the furniture producer will spend the next
three to six months producing furniture to fill these orders. The largest furniture mart is held in April and October in High Point, North Carolina. Other important marts are held in Chicago, Dallas, Los Angeles and San Francisco.
1 Hair, D., Hardwood Market Outlook, 1977 John S. Wright Forest Conference, Purdue University, Department of Forestry, West Lafayette, Indiana, 1977, p. 26.


4 A sawlog is a log that is at least 8 feet long, 8 inches in diameter and is clear and straight.

5 Although there are exceptions to this rule of thumb, European and other foreign demanders tend to buy the very highest grades of lumber. The only exception of this rule is hardwood lumber that goes to Canada. Domestic buyers also buy lumber of grades One Common and Better, although some Two Common is usually mixed in with the higher grade lumber.
CHAPTER III
MODEL DEVELOPMENT

The initial section of this chapter is a review of the assumptions underlying the theory of the firm. Using these assumptions the general relationships for output supply and the input demand for an individual firm and an entire market are formulated. This section is followed by a review of previous econometric studies of various forest product markets. The review of literature is followed by a discussion of lag structures and methods of implementing lag structures into econometric models. The supply, demand and price relationships for the hardwood lumber are presented using information discussed in Chapter II and the first three sections of the current chapter. Since there are two major demanders of hardwood lumber, separate demand relationships will be presented for pallet and furniture manufacturers in the development of the aggregate demand relationships. The concluding section of this chapter will be a presentation of the entire market model.

THE THEORY OF THE FIRM

The theory of the firm as presented by Mosak (19), Carlson (6), Ferguson (7), and others, assumes a perfectly competitive market in which actions taken by an individual firm do not affect input or output prices. Furthermore, firm managers are assumed to be rational in an economic sense which implies that these managers will combine their resources in a manner which will maximize the firm's objectives. If
the firms objective is to maximize profit then the rational manager would be a profit maximizer. Also resources (inputs) are assumed to be perfectly mobile, i.e., resources can be reallocated easily and instantaneously and decisions concerning the reallocation of resources can be made and implemented immediately. Another assumption is that inputs are purchased and completely exhausted and output is produced and sold during the production period. The length of a production period is arbitrary.

Two other interrelated perfect market assumptions are perfect knowledge and absence of risk. One definition of the perfect knowledge assumption is that the firm has access to information concerning future prices and constraints relevant to the firm's decision making. If the information is indeed correct, then decisions are made in the absence of any risk. However, if perfect knowledge is realistically defined to include information on the distribution of future prices and constraints relevant to decision making, then decisions based on perfect information can contain some element of risk.

A central physical principle underlying the theory of the firm is the law of diminishing returns. This principle entails the concept of the marginal product which is the change in output obtained by the addition of a one unit of a variable input, holding all other inputs constant. The law of diminishing returns states that a point will be reached where the marginal product will decrease as the amount of the variable input is increased. The profit maximizing level of production is where the value of an additional unit of output is equal to the cost
of the additional input used in the production of the output. Many times this profit maximizing level is stated as the point where marginal value of the product is equal to marginal cost of the input.

Since the competitive firm cannot influence input and output prices, profit maximizing decisions made by the firm are based on market prices. The market price of a good is the price at which demanders are willing to purchase the amount that suppliers are willing to sell, i.e. the market clearing price. If the firm is assumed to be producing at the profit maximizing output level, then the firm is using an optimal mix of inputs. There is only one mix of inputs that is efficient for each level of output, therefore, there is only one mix of inputs for the profit maximizing output level. When the price of an input or the price of the output changes, then both the profit maximizing level of output and the optimal input mix change.

The supply function expresses the quantity the firm will produce as a function of the price of output and prices of inputs. Since the profit maximizing firm produces where marginal revenue equals marginal cost, the firms supply curve is the part of the firms marginal cost curve lying above the average variable cost curve. The derived demand for an input expresses quantity of an input demanded by the firm as a function of price of the input, price of other inputs and the price of the output.

The short-run supply and derived input demand functions discussed above were for an individual firm. However, economists are often interested in market supply and demand relationships, i.e. industry wide
relationships. The market run supply curve is the horizontal summation of the marginal cost curves for every firm in the industry, while, the market demand curve for an input is the horizontal summation of all derived demands for that input. Since the industry-wide demand and short-run supply relationships are of interest in this study, all reference to the words demand and supply will henceforth refer to the industry wide, or market demand and short-run supply relationships unless stated otherwise.

REVIEW OF LITERATURE

Literature pertaining to the structure and behavior of the hardwood lumber market is fragmentary and descriptive in nature. However, econometric analyses of the softwood lumber market have been completed by McKillop (17) and Manning (16). Gregory (9) analyzed the hardwood flooring market and McKillop (18) analyzed the redwood lumber market. A general model for competitive commodity markets has also been developed by Labys (15).

The primary objective of Gregory's 1960 analysis of the hardwood flooring market was to apply econometric techniques developed in other disciplines to the analysis of hardwood product markets. Gregory developed a recursive system with quantity supplied being a function of past price, while, flooring price and flooring demand were dependent on current levels of their respective independent variables. Gregory's conclusion was that the recursive system seemed "reasonably appropriate", and stated that modern econometric methods can provide
insights regarding forest product markets.

The preliminary objective of McKillop's 1967 study was to specify aggregate demand and supply relationships for lumber, paper, paperboard, plywood, roundwood and stumpage. The main objectives of the study were to estimate the parameters for the above relationships and to predict future price and quantity levels.

McKillop hypothesized a simultaneous system of equations to explain the forest product market and estimated this system using two stage least squares techniques. Stepwise regression procedures were used to eliminate variables that did not contribute significantly to the total fit of a particular equation. Although McKillop investigated the entire wood product industry, only the relationships for the demand and supply of lumber are relevant to the current study.

The final estimated form of McKillop's demand for lumber cast quantity demanded as a function of prices of lumber, paperboard and plywood, and five year lagged price ratios of plywood, building board and steel relative to lumber. Other variables included were freight rates and value of construction. The lagged price ratios were included to account for the long-run substitution of lumber for other materials. Estimated demand elasticities were -3.5 for price of lumber, 1.3 for price of plywood and -1.8 for wages in construction.

The supply relationship estimated by McKillop related quantity of lumber supplied to prices of lumber, electricity, petroleum products and labor. Other variables included in this relationship were trend, tariff on lumber, exchange rates, productivity in sawmills and post and pre
World War II zero-one dummy variable. Estimated supply elasticities were .8 for price of lumber, .81 for wages in sawmills and -1.36 for price of electricity.

The objective of McKillop's 1969 econometric study of the redwood lumber market was to estimate a system of equations which would explain production, demand, stocks and prices of redwood lumber. The estimated system was recursive, but not in the usual sense because demand and not supply was estimated as a function of prices in previous periods. The reasoning behind this specification was that the buyers of redwood lumber may be unable to substitute materials in response to a price change during the current period. Furthermore, price expectations, which are made with consideration of prices in previous periods, may be an important demand determinate.

Manning's 1975 analysis of the Canadian softwood lumber industry resulted in the development and estimation of a system of equations that would permit the portrayal of the interdependencies of various domestic (Canadian) and foreign markets which are served by this industry. The estimated system contained domestic supply and demand equations, and also included export demand equations for the United States and all other countries in aggregate. This system of equations was assumed to be simultaneous and was estimated by two stage least squares. Numerous variables were tried in each of the equations. The final estimated demand equations indicated that housing starts were strongly related to quantity of lumber demanded by respective demanding regions, while, supply seemed to be highly related to lagged price of logs.
The basic commodity market model as developed by Labys is similar to Gregory's specification in that the econometric system presented is composed of a demand, supply and price model. The specification of each of these relationships included the lagged dependent variable. The coefficient of adjustment can be calculated by subtracting the estimated parameter for the lagged dependent variable from one, thus, giving the model a dynamic nature. The derived demand for an input is specified as the price of the input, the price of other inputs and economic activity level. Supply is specified as a function of lagged price, natural factors and government policy variables. Commodity price is specified as a function of quantity demanded and change in the level of inventories.

LAG STRUCTURES

Econometric analysis involves developing and estimating an equation or system of equations which are hypothesized to represent some economic phenomenon. If the economic phenomenon exists in a perfectly competitive market where there is immediate and complete reaction to any stimuli, then the elasticities estimated from these models can be considered both the short-run and long-run elasticities. However, when there is not full adjustment to an economic stimuli in the current time period, the concepts of lag structures, distributed lags and dynamic adjustment need to be considered in model development.

Lagged responses or adjustments are usually attributed to psychological factors such as the learning process, blocks or delays in
the transmission of market information, technical factors such as the inability to change the physical plant immediately and institutional reasons such as contracts. Since prices and other variables are continually changing, the estimated elasticities usually never represent full adjustment to changes in the independent variables. Therefore, long-run elasticities are difficult to estimate.

There are several methods of incorporating lag structures into econometric models. The easiest method of specifying a lag structure involves using previous (lagged) values of the predetermined variables as regressors in the model. Other methods which have been developed by Nerlove (23), Koyck (13), Almon (3) and others allow the effects of past values of predetermined variables to be distributed over several time periods. These type of lag structures are termed distributed lags.

Nerlove (23) developed an explicit dynamic model in which a distributed lag may be incidentally developed. Operationally, the Nerlovian lag structure is incorporated into the model by the addition of the lagged dependent variable as an explanatory variable. After estimating the model, a coefficient of adjustment can be calculated by substracting the estimate for the lagged dependent variable from one. The Nerlovian method can be used in conjunction with lagged values of exogenous and other endogenous variables to form a more complex lag structure.

One major drawback of the Nerlovian method is that the error term is correlated with the lagged endogenous variable, therfore, the resulting estimates are biased. A discussion on the mechanics, problems
and theory behind the Nerlovian lag structure is presented and discussed in Appendix A.

Griliches (8) suggested that when using a lagged dependent variable with data that is trending, something should be done about trend removal. If trend is not accounted for in the model, the coefficient on the lagged dependent variable may be influenced by the trend. Therefore, a time trend variable is often included in models with lagged dependent variables.

**SUPPLY OF HARDWOOD LUMBER**

The supply relationship to be estimated in this study is:

\[(3.1) \quad \text{QHLS}_t = f(\text{QHLS}_{t-1}, \text{PHL}_t, \text{TCS}_{t,t-1}, \text{PLHS}_t, \text{PE}_t, R_{t,t-k}, T)\]

where:

- \(\text{QHLS}_t\) = Quantity of hardwood lumber supplied in time period \(t\),
- \(\text{QHLS}_{t-1}\) = Quantity of hardwood lumber supplied in time period \(t-1\),
- \(\text{PHL}_t\) = Price of hardwood lumber in time period \(t\),
- \(\text{TCS}_{t,t-1}\) = Total cost of stumpage in period \(t\) and previous time periods, including the component cost of borrowing money,
- \(\text{PLHS}_t\) = Price of labor in hardwood sawmills in time period \(t\),
- \(\text{PE}_t\) = Price of energy in time period \(t\),
- \(R_{t,t-k}\) = The rate of interest in period \(t\) and the rates of interest in previous time periods,
- \(T\) = Time trend.
Equation 3.1 is similar to the general form presented by Labys in that quantity supplied is a function of lagged quantity supplied, price of output and prices of inputs. Lagged quantity was included in the specification to allow for dynamic adjustment. If the coefficient associated with lagged quantity is less than zero, then the long-run elasticity will be the opposite sign of the short-run elasticity. If this coefficient is greater than 1, then the long-run elasticity will be less than the short-run elasticity. Since the long-run elasticity is expected to be larger and have the same sign as the short-run elasticity, the coefficient associated with lagged quantity is expected to be positive and less than one.

The coefficient associated with price of lumber is expected to be positive since lumber production should increase with increased lumber price. The coefficients associated with wage rate, price of stumpage, price of energy and rate of interest are expected to be negative since lumber production should decrease given an increase in price of one or more of these inputs.

As mentioned in Chapter II, roundwood inputs may be purchased in the form of stumpage, sawlogs, a combination of stumpage and sawlogs, or the timber may be owned by the firm. Stumpage price was included in the supply relationship instead of sawlog price because there is no sawlog price series of adequate length available. Since sawlogs are an input which are purchased and utilized shortly after purchase, there are no violations of the resource mobility assumption. However, hardwood stumpage may be purchased and then held for a time period before
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harvesting. Thus, stumpage price in the previous year may have an effect on current lumber supply. Therefore, the price of stumpage is expressed as a function of current and past price rather than just current price.

The specification of equation 3.1 implicitly assumes no simultaneous interaction between the stumpage market and the lumber market. Although conditions in the lumber market eventually affect the price of stumpage, large inventories of sawtimber and lack of communication between the stumpage owners and stumpage users causes the price of stumpage to be a function of past rather than current conditions in the lumber market. Therefore, hardwood lumber supply can be statistically estimated independently of the demand for stumpage without introduction of least squares bias into the equation.

Since stumpage is a relatively high cost input, the time value of money or interest rate, must be considered as part of the cost of purchasing stumpage for more than one production period. Interest rates are part of the cost of purchasing stumpage because the mill operator purchases stumpage with borrowed funds or with funds from the firm's reserves. If funds are borrowed then, the rate of interest represents the cost of borrowed funds. If funds are obtained from the firm's reserves, then interest rate represents the opportunity cost of the money. In either case, the total cost of stumpage is the cost of the stumpage plus the amount of interest paid, or interest forgone, in purchasing or owning the stumpage. Previous purchases of capital also affect current lumber production. Therefore, a past and current
interest rate have been included in equation 3.1.

The time trend variable is expected to account for technological change especially with respect to changes in labor productivity. These expectations are based on the fact that the number of production workers has decreased by 55 percent during the last 30 years, while, lumber production has remained relatively constant.3

AGGREGATE LUMBER DEMAND

Pallet and furniture manufacturers accounted for 70 percent of the lumber used in 1977. Therefore, separate demand relationships will be presented for these industries. Although data limitation do not facilitate the estimation of these individual demand relationships, the insight gained from their specification will aid in the development of the aggregate demand specification.

Furniture Manufacturers Demand

The demand relationship for the furniture industry can be stated as follows:

\[
\text{(3.2) } Q_{HLDF_t} = g(Q_{HLDF_{t-1}}, W_{PF_t}, P_{HL_{t-m}}, P_{LF_{t-m}}, P_{E_{t-m}}, P_{S_{t-m}}, R_{t,t-k,T})
\]

where:

\[Q_{HLDF_t} = \text{Quantity of hardwood lumber demanded by furniture manufacturers in time period } t,\]
Equation 3.2 is similar to the general demand function presented by Labys in that quantity demanded is a function of lagged quantity demanded, price of lumber, price of other inputs and the price of output. This specification is also similar to the redwood lumber demand relationship developed by McKillop in which quantity demanded is expressed as a function of lagged rather than current lumber price.

Lagged quantity was included in the specification to allow for dynamic adjustment. The coefficient associated with lagged quantity demanded is expected to be positive and less than one. The coefficient associated with lagged lumber price is expected to be negative because lumber is an input in furniture production. Since labor, energy and capital are assumed to be complimentary inputs, with lumber the coefficients associated with lagged these variables are also expected to be negative. The price of substitute materials are expected to be positively related to quantity of lumber demanded because lumber use will increase, given an increase in the price of lumber substitutes. The lag
period associated with all input prices is expected to be the same.

The time trend variable is expected to account for technological change. Technological changes have especially occurred with respect to changes in labor productivity. Output per man hour in furniture manufacturing has increased 248 percent in the last 20 years.4

Quantity of lumber demanded by furniture manufacturers is expressed as a function of past rather than current prices of inputs because of the method in which furniture is designed, produced and marketed. The period between the design period and the actual production of furniture may be greater than one year. The implication of this lag between designing and production of furniture is that past decisions affect current material use. Since these decisions are made prior to production, they are based on price expectations rather than currently existing prices.

Expectations of future prices may be based on the current price and prices in previous time periods. Therefore, expectations of price next year may be based on the current price and last year's price. It should be noted that price expectations may also affect current use of materials other than lumber and current labor use.

Since past decisions may drastically affect current profits, some firms may hedge the risk of a large price change through forward contracts. A forward contract may be a verbal or written agreement with a lumber supplier, and may exist in the case of firms with captive sawmills. However, the practice of forward contracting does not appear to be widespread in the furniture industry.
The assumption that resources are purchased and consumed during the production period is violated when considering capital inputs. Physical plant and machinery are inputs which can be used for several years. Therefore, past prices of capital inputs affect current furniture production and, in turn, affect furniture manufacturers' current lumber use.

The price of output enters into the derived demand for furniture in a different way than is normally dictated by economic theory. According to the theory of the firm, a firm decides how much to produce based on the price of the inputs and price of the output. However, furniture is produced on orders placed by furniture buyers. These furniture buyers base their purchasing decisions on either the retail or wholesale price of furniture. Therefore, the output price which influences furniture manufacturing use of for lumber is the retail or wholesale price of furniture.

Pallet Manufacturers' Demand

The demand relationship for the pallet industry can be stated as:

\[
(3.3) \ Q_{HLD}^t = g(Q_{HLD}^{t-1}, P_{OD}^t, P_{HL}^{t-n}, P_{LP}^{t-n}, P_{E}^{t-n}, P_{S}^{t-n}, \\
R_{t,t-j}, T)
\]

where:

\[Q_{HLD}^t = \text{Quantity of hardwood lumber demanded by pallet manufacturers in time period } t,\]
Equation 3.3 is similar to the specification of the furniture manufacturers' demand relationship. Quantity of lumber demanded is again expressed as a function of past prices of inputs and the price of pallet demanders output.

The coefficient associated with lagged quantity is again expected to be positive and less than one. The price of lumber, price of energy, wage rate and rate of interest are expected to be negatively related to quantity of lumber demanded since all are complimentary inputs with lumber. Price of output and price of substitute materials are again expected to be positively related to quantity demanded. The lagged period associated with all input prices is expected to be the same.

Pallet manufacturers' lumber demand is similar to furniture manufacturers' demand in that current lumber use is affected by past decisions. Therefore, quantity of lumber demanded by pallet manufacturers', can be expressed as a function of lagged prices of inputs and current price of output of pallet demanders. However, there are different reasons for these similar end results.
Pallets are produced on order or on long term contract. Also pallet manufacturers are locked into a fixed proportions production process in the short-run. Although labor and other material may be substituted for lumber, the amount of substitution that can occur in the short-run is small because pallet design and pallet producing machinery do not change in the short-run. However, significant changes in pallet design and the production process can occur in a two to three years period.

Pallets are produced on orders placed by businesses which use pallets for material handling. When current prices of manufactured goods increase relative to cost of the inputs, production of these goods increases, and the demand for pallets increases. Since manufacturers are locked into their material handling system in the short-run and pallet expense is usually a small part of the manufacturers total cost, demand for pallets may increase even if pallet costs are rising moderately when industrial production increases.

Aggregate Demand

In the last two sections of this chapter the demand for hardwood lumber by the two major users was expressed as a function of lagged input prices and current output prices. The reason for this lag structure was that decisions concerning future production are based on expectations of price rather than current price. Since pallet and furniture manufacturers use nearly seventy percent of the hardwood lumber used in the United States, the aggregate demand for hardwood lumber should be similar to the demands by these industries. Therefore,
the aggregate demand of hardwood lumber can be stated as follows:

\[ (3.4) \quad Q_{HLD_t} = g(Q_{HLD_{t-1}}, P_{O_t}, P_{HL_{t-1}}, P_{L_{t-1}}, P_{E_{t-1}}, R_{t-i}, T) \]

where:

- \( Q_{HLD_t} \) = Aggregate quantity of hardwood lumber demanded in time period \( t \),
- \( Q_{HLD_{t-1}} \) = Aggregate quantity of hardwood lumber demanded in time period \( t-1 \),
- \( P_{O_t} \) = Price of output of for industries which use of hardwood lumber in time period \( t \),
- \( P_{HL_{t-1}} \) = Price of hardwood lumber lagged \( 1 \) periods,
- \( P_{L_{t-1}} \) = Price of labor in industries which use hardwood lumber lagged \( 1 \) periods,
- \( P_{E_{t-1}} \) = Price of energy lagged \( 1 \) periods,
- \( R_{t-i} \) = The rate of interest lagged \( i \) periods,
- \( T \) = Time trend.

In equation 3.4 the coefficient associated with lagged quantity is again expected to be positive and less than one. Price of hardwood lumber, labor, energy and interest rate are expected to be negatively related to quantity of hardwood lumber demanded. The time trend variable is expected to account for technological change especially with respect to changes in labor productivity. Therefore, time is expected to be positively related to quantity of hardwood lumber demanded.

The price of substitute materials was not included in the aggregate demand relationship because during the last 20 years a series of differing substitutes have been developed, implemented, then replaced by yet another substitute material. An example of this situation is the
use of substitute materials in the furniture industry. In the 1960's plastics such as polyurethane were used in the production of lower priced furniture, while in the 1970's, embossed poplar and medium density fiber-board were used in the production of lower end furniture.

Since quantity demanded is hypothesized to be dependent on lagged price, and quantity supplied is dependent on current price, the resulting system is similar to the cobweb model which has been used to describe many agricultural commodity markets and the redwood demand relationship developed by Mckillop.

THE PRICE OF HARDWOOD LUMBER

In the theory of the firm, it is assumed that firms are numerous, inventories do not exist and price is determined endogenously by the forces of supply and demand. When the quantity demanded equals the quantity supplied at the market clearing price the market is said to be in equilibrium. Hardwood lumber price is also determined endogenously, in a competitive market structure and by the interaction of supply and demand. However, inventories held by lumber producers and lumber wholesalers act as a buffer between quantity demanded and quantity supplied; so quantity demanded during a specific period does not have to equal quantity supplied. Therefore, price cannot be viewed as the simple interaction of supply and demand, but the levels of inventories have to be considered. Using the framework developed by Labys (15) the price of lumber and levels of inventories can be expressed as:

\[ PHL_t = h(PHL_{t-1}, OHLD_t, OHLE_t, INV_t) \]
and

\[ (3.6) \quad \text{INV}_t = \text{INV}_{t-1} + \text{QHLS}_t - \text{QHLD}_t - \text{QHLE}_t \]

where:

- \( \text{PHL}_t \) = Price of hardwood lumber time period \( t \),
- \( \text{PHL}_{t-1} \) = Price of hardwood lumber time period \( t-1 \),
- \( \text{QHLD}_t \) = Aggregate quantity of domestic hardwood lumber demanded by domestic users in time period \( t \),
- \( \text{QHLE}_t \) = Quantity of domestic hardwood lumber exported in time period \( t \),
- \( \text{INV}_t \) = Quantity of hardwood lumber held at sawmills and concentration yards during period \( t \),
- \( \text{INV}_{t-1} \) = Quantity of hardwood lumber held at sawmills and concentration yards lagged one period,
- \( \text{QHLS}_t \) = Quantity of hardwood lumber supplied in time period \( t \).

The specification of equation 3.6 deviates from Labys' general model in that Labys' model does not include export demand in the price equation. Lumber exports are hypothesized to affect domestic lumber price in a positive manner, i.e., when export demand increases the price of hardwood lumber increases. Although hardwood lumber exports account for less than 5 percent of the lumber produced domestically, it accounts for a large share of the demand for lumber of the highest grades. Increases in foreign demand result in increases in the price of grades first and seconds (F.A.S.) lumber, which may in turn lead to a rise in the price of grade One Common lumber and lumber of lower grades.
The coefficient associated with lagged price is called the coefficient of price expectation and is expected to be positive but less than one. If this coefficient is greater than one the equation will be explosive. A coefficient value less than zero would indicate that expectations of future price is the opposite of current trends.

Quantity demanded and quantity exported are expected to be positively related to price since an increase in quantity demanded leads to an increase in price given supply remains constant. Inventory levels are expected to be negatively related to price since increasing inventories signal that production is exceeding usage and therefore, price must drop.

Equation 3.6 should be thought of as a relationship which represents the price formation process. Current demand conditions are represented by aggregate quantity demanded and quantity exported. Supply conditions enter through the identity and are represented by the inventory variable. If demand increases while supply stays the same, inventories will decrease. If Walrasian stability is assumed, then a decrease in inventories is a signal to the lumber suppliers to ask for a higher price, while a build up of inventories is a signal to the lumber buyers to offer a lower price.

Expectations enter into the price formation process by acting as a reference point to the buyers and sellers of hardwood lumber. Buyers and sellers negotiate a price based on past price and the current demand and supply of lumber. Even though the lumber buyers are locked into a predetermined quantity of lumber needed, they are still in a position to
negotiate because if one seller sets the price too high, a competitor
may be willing to sell at a lower price.

THE MODEL

The general model representing the hardwood lumber market is formed
by combining equations 3.1, 3.4, 3.5 and identity 3.6.

\[QHLS_t = f(QHLS_{t-1}, PHL_t, TCS_{t,t-j}, PLHS_t, PE_t, R_{t,t-h}, T)\]

\[QHLD_t = g(QHLD_{t-1}, PO_t, PHL_{t-1}, PL_{t-1}, PE_{t-1}, R_{t-1,h}, T)\]

\[PHL_t = h(PHL_{t-1}, QHLD_t, QHLE_t, INV_t)\]

\[INV_t = INV_{t-1} + QHLS_t - QHLD_t - QHLE_t\]

where:

- \(QHLS_t\) = Quantity of hardwood lumber supplied in time period \(t\),
- \(QHLS_{t-1}\) = Quantity of hardwood lumber supplied in time period \(t-1\),
- \(QHLD_t\) = Aggregate quantity of hardwood lumber demanded in time period \(t\),
- \(QHLD_{t-1}\) = Aggregate quantity of hardwood lumber demanded in time period \(t-1\),
- \(PHL_t\) = Price of hardwood lumber in time period \(t\),
- \(PHL_{t-1}\) = Price of hardwood lumber in time period \(t-1\),
- \(INV_t\) = Lumber held in inventories in time period \(t\),
- \(INV_{t-1}\) = Lumber held in inventories in time period \(t-1\),
- \(TCS_{t,t-j}\) = Total cost of stumpage in period \(t\) and the previous time period,
- \(PLHS_t\) = Price of labor in hardwood sawmills in time period \(t\),
PE\textsubscript{t} = Price of energy in time period t,
R\textsubscript{t,t-h} = The rate of interest in period t and the rates of interest in previous time periods,
PO\textsubscript{t} = Price of output in time period t for industries which use hardwood lumber,
PHL\textsubscript{t-r} = Price of hardwood lumber lagged r periods,
PL\textsubscript{t-r} = Price of labor in industries which use hardwood lumber lagged r periods,
PE\textsubscript{t-r} = Price of energy lagged r periods,
R\textsubscript{t-h} = The rate of interest lagged h periods,
QHLE\textsubscript{t} = Quantity of domestic hardwood lumber exported in time period t,
T = Time trend.

The general market model is hypothesized to be recursive with the causal flow originating from the demand equation, continuing through the price relationship, and ending in the supply relationship. Since the system is recursive, each equation can be estimated separately by ordinary least squares.
FOOTNOTES

1 Havlicek, J., Jr., Lecture Notes In Econometric Methods An Analysis, Department of Agricultural Economics and Department of Statistics, Virginia Tech, 1980, p. 10-4.

2 There are some distinct differences between the eastern hardwood stumpage market and the western softwood stumpage market. Hardwood stumpage is usually cut 1 month to 2 years after it is purchase. However, softwood stumpage may be purchased then held for 1 to 5 years before being cut. Furthermore, softwood stumpage may be purchased for speculation, where as hardwood stumpage is usually purchased for the pure intent of harvesting the logs.

3 The number of production workers at sawmills decreased from 463,000 in 1950 to 209,000 in 1978. Source: Statistical Abstracts of the United States.

4 The index of furniture production has increased from 52, in 1950 to 156, in 1978. During this time period production workers have only increase from 317,000 to 407,000 and hours worked per week decreased from 41.8 to 39.3. Source of production information, Statistical Abstracts of the United States. Source of employment statistics, Employment and Earnings in the United States, 1909-1975, and Supplement to Employment and Earnings, 1980.
CHAPTER IV
AGGREGATE SUPPLY DEMAND AND PRICE

This chapter presents the estimated hardwood market model. The model is composed of three equations representing the supply, demand and price relationships discussed in Chapter III. The estimated results of each relationship will be presented in separate sections. The presentation of these results will be preceded by a discussion of the data base and followed by a discussion of the implications which can be drawn from the estimated model. Since the market model is assumed to be recursive, a statistical test for correlation of the error terms between the estimated supply, demand and price equations is presented in Appendix B as a test for simultaneity.

DATA BASE

The models presented in this section were estimated from secondary data. Data pertaining to quantity supplied and inventory levels were collected from Lumber Production and Mill Stocks, "Current Industrial Reports". Quantity exported was obtained from "U. S. Exports by Commodity by Country, Federal Trade Report 410". All price indices and actual prices were obtained from "Statistical Abstracts of the United States". Price indices were used in place of actual prices when an appropriate series of actual prices was unavailable.

Quantity demanded was calculated using the following identity.
(4.1) \( QHLD_t = QHLS_t + INV_{t-1} - INV_t - QHLE_t \)

where:

\( QHLD_t \) = Quantity of hardwood lumber demanded in time period \( t \),

\( QHLS_t \) = Quantity of hardwood lumber supplied in time period \( t \),

\( INV_{t-1} \) = Inventories of hardwood lumber in time period \( t-1 \),

\( INV_t \) = Inventories of hardwood lumber in time period \( t \),

\( QHLE_t \) = Quantity of hardwood lumber exported in time period \( t \).

Identity 4.1 is a rearrangement of identity 3.6 presented in the previous chapter. In actuality, identity 4.1 represents total domestic disappearance of domestically produced lumber rather than quantity of lumber demanded. However, it is assumed that total domestic disappearance is equal to quantity demanded.

The data base used in this study spans the period 1959-1978. The length of the data base was limited by the length of the stumpage price series.

ESTIMATION OF HARDWOOD LUMBER SUPPLY

Aggregate hardwood lumber supply and oak lumber supply equations are presented in this section.\(^1\) Aggregate supply equations were estimated for the entire United States and for the Eastern, Northeastern and Southeastern regions of the United States.\(^2\) Regional supply relationships were estimated in order to determine if these relationships were similar or different with respect to the input and
output price elasticity of demand. Oak production data for the entire United States was unavailable therefore, oak supply equations were only estimated for the Eastern, Northeastern and Southeastern regions.

The formulation of the supply equations is:

\[(4.2) \quad Q_{HLS_t} = f(Q_{HLS_{t-1}}, P_{HL_t}, TCS_{t,t-1}, P_{LS_t}, R_{t,t-2}, T)\]

where:

- \(Q_{HLS_t}\) = Quantity of lumber supplied (million bf) in time period \(t\),
- \(Q_{HLS_{t-1}}\) = Lagged quantity of lumber supplied,
- \(P_{HL_t}\) = Price index for hardwood lumber (in nominal dollars 1967 = 100) in time period \(t\),
- \(TCS_{t,t-1}\) = Two year moving average of this year's and last year's total price of stumpage (in nominal dollars per thousand bf) which includes the cost of borrowing money for one year to pay for the stumpage,
- \(P_{LS_t}\) = Price of labor in sawmills (in nominal dollars per hour) in time period \(t\),
- \(R_{t,t-2}\) = Three year moving average of the annual average rate of 4 to 6 month prime commercial paper,
- \(T\) = Time trend, (1959 = 1 and then increasing one unit per year).

The results of the estimated aggregate lumber supply equations are presented by region in Tables 4 and 6, while the results of the oak supply equations are presented on Tables 5 and 7. All equations were estimated in double log form and thus the estimated coefficients of the price variables presented in Table 4 and 6 represent estimates of short-run elasticities. The elasticities of adjustment for the various equations is one minus the coefficient of the lagged quantity. The
TABLE 4  Estimated Aggregate Supply Equation for Hardwood Lumber by Region of the United States 1960-1978

<table>
<thead>
<tr>
<th></th>
<th>United States</th>
<th>Eastern U.S.</th>
<th>Northeast U.S.</th>
<th>Southeast U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>6.50</td>
<td>5.01</td>
<td>4.56</td>
<td>5.51</td>
</tr>
<tr>
<td></td>
<td>(1.09)a</td>
<td>(1.23)a</td>
<td>(1.06)a</td>
<td>(1.56)a</td>
</tr>
<tr>
<td>Lagged Quantity</td>
<td>.098</td>
<td>.263</td>
<td>.228</td>
<td>.127</td>
</tr>
<tr>
<td></td>
<td>(.127)</td>
<td>(.145)b</td>
<td>(.149)c</td>
<td>(.190)</td>
</tr>
<tr>
<td>Lumber Price</td>
<td>.670</td>
<td>.664</td>
<td>.549</td>
<td>.847</td>
</tr>
<tr>
<td></td>
<td>(.110)a</td>
<td>(.117)a</td>
<td>(.137)a</td>
<td>(.185)a</td>
</tr>
<tr>
<td>2 Year Moving Average of Stumpage Cost</td>
<td>-.432</td>
<td>-.412</td>
<td>-.367</td>
<td>-.510</td>
</tr>
<tr>
<td></td>
<td>(.086)b</td>
<td>(.094)a</td>
<td>(.109)a</td>
<td>(.149)a</td>
</tr>
<tr>
<td>Labor Price</td>
<td>-.762</td>
<td>-.710</td>
<td>-.577</td>
<td>-.957</td>
</tr>
<tr>
<td></td>
<td>(.100)a</td>
<td>(.111)a</td>
<td>(.110)a</td>
<td>(.180)a</td>
</tr>
<tr>
<td>3 Year Moving Average of Interest Rate</td>
<td>-.187</td>
<td>-.180</td>
<td>-.163</td>
<td>-.205</td>
</tr>
<tr>
<td></td>
<td>(.043)a</td>
<td>(.049)a</td>
<td>(.064)a</td>
<td>(.077)a</td>
</tr>
<tr>
<td>Time Trend</td>
<td>.392</td>
<td>.350</td>
<td>.419</td>
<td>.394</td>
</tr>
<tr>
<td></td>
<td>(.052)a</td>
<td>(.055)a</td>
<td>(.059)a</td>
<td>(.083)a</td>
</tr>
<tr>
<td>R-Square</td>
<td>.945</td>
<td>.932</td>
<td>.951</td>
<td>.912</td>
</tr>
<tr>
<td>F-Value</td>
<td>31.6</td>
<td>25.3</td>
<td>35.6</td>
<td>19.0</td>
</tr>
</tbody>
</table>

Note: All models are in double log or multiplicative form, therefore all coefficients represent short run point elasticities.

a: significant at the .01 level
b: significant at the .05 level
c: significant at the .10 level
d: significant at the .15 level
**TABLE 5** Long Run Elasticities for Aggregate Supply of Hardwood Lumber by Regions of the United States, 1960-1978

<table>
<thead>
<tr>
<th></th>
<th>United States</th>
<th>Eastern U.S.</th>
<th>Northeast U.S.</th>
<th>Southeast U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumber Price</td>
<td>.743</td>
<td>.901</td>
<td>.711</td>
<td>.970</td>
</tr>
<tr>
<td>2 Year Moving Average of Stumpage Cost</td>
<td>-.479</td>
<td>-.559</td>
<td>-.475</td>
<td>-.584</td>
</tr>
<tr>
<td>Labor Price</td>
<td>-.846</td>
<td>-.963</td>
<td>-.747</td>
<td>-1.10</td>
</tr>
<tr>
<td>3 Year Moving Average of Interest Rate</td>
<td>-.207</td>
<td>-.240</td>
<td>-.211</td>
<td>-.235</td>
</tr>
</tbody>
</table>
TABLE 6 Estimated Supply Equations for Oak Lumber by Regions of the United States, 1960-1978

<table>
<thead>
<tr>
<th></th>
<th>Eastern U.S.</th>
<th>Northeast U.S.</th>
<th>Southeast U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>4.84</td>
<td>3.96</td>
<td>5.94</td>
</tr>
<tr>
<td></td>
<td>(1.95)b</td>
<td>(1.23)a</td>
<td>(2.39)b</td>
</tr>
<tr>
<td>Lagged</td>
<td>.277</td>
<td>.362</td>
<td>.120</td>
</tr>
<tr>
<td>Quantity</td>
<td>(.243)c</td>
<td>(.170)b</td>
<td>(.295)</td>
</tr>
<tr>
<td>Lumber Price</td>
<td>.360</td>
<td>.332</td>
<td>.313</td>
</tr>
<tr>
<td></td>
<td>(.117)a</td>
<td>(.098)a</td>
<td>(.146)b</td>
</tr>
<tr>
<td>2 Year Moving Average of Stumpage Cost</td>
<td>-.160</td>
<td>-.211</td>
<td>-.097</td>
</tr>
<tr>
<td></td>
<td>(.108)c</td>
<td>(.088)b</td>
<td>(.129)</td>
</tr>
<tr>
<td>Labor Price</td>
<td>-.401</td>
<td>-.282</td>
<td>-.523</td>
</tr>
<tr>
<td></td>
<td>(.172)b</td>
<td>(.113)b</td>
<td>(.205)b</td>
</tr>
<tr>
<td>3 Year Moving Average of Interest Rate</td>
<td>-.142</td>
<td>-.153</td>
<td>-.151</td>
</tr>
<tr>
<td></td>
<td>(.074)b</td>
<td>(.062)b</td>
<td>(.093)c</td>
</tr>
<tr>
<td>Time Trend</td>
<td>.165</td>
<td>.248</td>
<td>.171</td>
</tr>
<tr>
<td></td>
<td>(.119)c</td>
<td>(.082)a</td>
<td>(.135)d</td>
</tr>
<tr>
<td>R-Square</td>
<td>.850</td>
<td>.949</td>
<td>.869</td>
</tr>
<tr>
<td>F-Value</td>
<td>10.4</td>
<td>33.7</td>
<td>12.8</td>
</tr>
</tbody>
</table>

Note: All models are in double log or multiplicative form, therefore all coefficients represent point elasticities.

a: significant at the .01 level
b: significant at the .05 level
c: significant at the .10 level
d: significant at the .15 level
TABLE 7 Long Run Elasticities for Oak Lumber Supply by Regions of the United States, 1960-1978

<table>
<thead>
<tr>
<th></th>
<th>Eastern U.S.</th>
<th>Northeastern U.S.</th>
<th>Southeastern U.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lumber Price</td>
<td>.498</td>
<td>.520</td>
<td>.335</td>
</tr>
<tr>
<td>2 Year Moving Average of Stumpage Cost</td>
<td>-.221</td>
<td>-.331</td>
<td>-.110</td>
</tr>
<tr>
<td>Labor Price</td>
<td>-.554</td>
<td>-.442</td>
<td>-.594</td>
</tr>
<tr>
<td>3 Year Moving Average of Interest Rate</td>
<td>-.196</td>
<td>-.240</td>
<td>-.172</td>
</tr>
</tbody>
</table>
long-run elasticities shown in Tables 5 and 7 were calculated by dividing the short-run elasticity by the elasticity of adjustment.

Aggregate supply was estimated as a function of lagged quantity, the wholesale price index of hardwood lumber, the price of labor in sawmills, a three year moving average of interest rate, a two year moving average of stumpage costs, and time. The rate of interest for 4 to 6 month prime commercial paper was used to calculate the moving average of interest rate. The stumpage cost variable was calculated as the average stumpage prices for sawtimber sold from National Forests, plus the cost of 4 to 6 month prime commercial paper assuming a loan payback period of one year.

Oak supply was estimated as a function of lagged quantity, price of Appalachian red oak One Common lumber, wage rate in sawmills, a three year moving average of interest rates, a two year moving average of stumpage cost and time. The moving averages for interest rates and stumpage costs were identical to the ones used in the aggregate model, except that average stumpage price for oak sawtimber sold from National Forest was used in calculating total stumpage price.

Although most hardwood stumpage is purchased from private sources, the only available stumpage price series of adequate length was National Forest stumpage price. Preliminary analysis revealed that National Forest stumpage prices were a multiple of price of stumpage purchased from private sources. Therefore, the resulting elasticities obtained by using National Forest stumpage prices in the supply relationships estimated in double log form are unbiased.
Because of a limited number of observations in the data base, interest rate was expressed as a three year moving average rather than separate variables for current and lagged prices, or a more complicated lag structure as the one developed by Almon (3). The problem in using a moving average is that current price and prices in previous years are assumed to have an equal amount of influence on current quantity supplied. The specific length of the moving average was not known a priori, but was expected to range between two and five years. The three year moving average was used in the final models because models with this lag specification had the highest F statistic and the smallest standard errors.

Stumpage cost was also expressed as a two year moving average rather than an alternative lag specification because of the limited number of observations in the data base. The one year payback period was assumed because hardwood stumpage is usually purchased in small tracts and therefore, loans made to purchase stumpage would usually be paid back within a year. If stumpage is purchased using the firm's internal funds, then the one year payback period represents the interest revenue forgone by not investing the funds in alternative ventures. The two year moving average was assumed since most hardwood stumpage is used within one or two years after it is purchased.

The price of energy was not included as a variable in the final specification of the supply equations. Numerous attempts at including energy costs into the supply relationships did not yield a significant increase in explanatory power of the equations and the estimated
coefficients for this variable were not significant in any of the equations in which it was tried. These results may stem from the difficulties of identifying energy costs since some mills produce energy from bark, saw dust and wood scraps while other mills purchase fuel or electricity. Also, energy costs may be small in relation to the costs of labor, capital and the roundwood input. Furthermore, energy usage is linked to capital equipment, thus energy is used in a fixed proportion to the level of output until the capital equipment is replaced.

The results presented in Tables 4 and 5 are consistent with a priori expectations in that the signs of the estimated coefficients correspond to theoretical considerations. Quantity supplied was estimated to be inversely related to the prices of stumpage and labor and the rate of interest rate. The sign associated with the price of output (price of lumber) is positive. The coefficient for lagged quantity variables were positive and less than 1 indicating that adjustment to changes in input and output prices do not fully occur in the time frame of the model specification.

The overall fit of the aggregate supply equations are good with the $R^2$ of all equations being above .90. All estimated coefficients are significant at the .01 level of significance, except for the coefficient associated with lagged quantity. The overall fits of the oak supply equations were good with all $R^2$'s being .85 and above, however, the significance level of the individual coefficients were not as high as in the aggregate equations.
The results in Table 4 suggest that lumber production in the Southeast responds more quickly to changes in input and output prices than does lumber production in the Northeast. The coefficient of the lagged quantity is small and not significantly different from zero for the Southeastern equation. These results indicate Southeast lumber supply adjusts rapidly to changes in the prices of lumber and labor. The results also indicate that the lumber supply in the Southeast responds to changes in interest rate in about three years and responds to changes in stumpage prices in about two years. However, the coefficient for lagged quantity for the Northeastern lumber supply equation is 80 percent larger than its counterpart in the Southeast lumber supply equation, indicating that Southeastern supply adjusts more quickly to price changes. The results in Table 4 and 5 also indicate that the supply in the Southeast is more elastic to changes in input and output price than is the supply in the Northeast. This difference is especially noticeable in the short-run elasticities, but is also evident in the case of the long-run elasticities presented in Table 5.

The aggregate supply for the eastern U. S. also has a significant coefficient for lagged quantity which is about the same in magnitude as the coefficient of lagged quantity in the Northeastern supply equation. The short and long-run price elasticities for the Eastern model seem to lie between the elasticities for the Southeastern and Northeastern equations. The results of all three supply equations indicate: (1) quantity supplied adjusts faster in the Southeast than in the Northeast; and, (2) quantity supplied tends to be more elastic with respect to
input and output prices in the Southeast than in the Northeast.

The results of the oak supply equations for the Southeastern and Northeastern regions are somewhat different from the results of the aggregate supply equations. Again the coefficient of the lagged quantity is small and insignificant in the Southeastern oak supply equation, while the coefficient of lagged quantity in the Northeastern equation is 3 times larger and statistically significant. The coefficient for lagged quantity for the Eastern supply equation lies between the value obtained in the Northeastern and Southeastern equations. However, the short and long-run elasticities for the price of lumber and price of stumpage are higher in the Northeastern oak supply than they are for Southeastern oak supply. The only long-run elasticity which is greater in the case of Southeastern supply is the one associated with the price of labor. The short-run elasticity for lagged interest rates are almost identical across equations but the Northeastern supply relationship has a more elastic supply in the long-run with respect to changes in interest.

Somewhat contradictory results for the aggregate and oak supply equations are that oak lumber supply is less elastic than aggregate supply with respect to input and output prices in both the short and the long-runs. It also appears that Northeastern oak supply is more elastic to input and output prices than the Southeastern supply, while the aggregate supply equation indicates the opposite. Only with respect to the price of labor was the Southeastern supply consistently more elastic than Northeastern supply. This latter observation may stem from labor
productivity differences between these regions, however, there is no other supporting evidence for this notion.

The estimated long-run price elasticity of lumber supply ranged between a low of .36 for Southeastern oak supply to a high of .97 for Southeastern aggregate supply. The short-run elasticities of lumber prices are relatively constant across regions for the oak supply equations, while they vary across regions for aggregate supply. Since oak production accounts for approximately 50 percent of all hardwood lumber production, the lower estimates of price elasticity for oak lumber relative to all hardwood lumbers indicates that the price elasticity of supply for species other than oak may be quite high. The long-run elasticity of lagged stumpage cost ranged between a low of -.11 for Southeastern oak supply to a high of -.58 for Southeastern aggregate supply. Again, the oak supply equations had lower elasticities for stumpage price than did the aggregate supply equations, indicating potentially higher stumpage price elasticities of supply for other species hardwood lumber.

The long-run labor price elasticity of supply ranged from -.44 for the Northeastern oak supply to -1.1 for the Southeastern aggregate supply. The high magnitude of the labor price elasticity relative to the elasticities of other inputs is indicates that labor costs are a large part of the cost of producing hardwood lumber.

The long-run elasticity for lagged interest rate ranged from -.17 for Southeastern oak supply to -.24 for Southeastern aggregate supply. It should be noted that this elasticity was similar across models with
Northeastern and Eastern supply equations having short-run elasticities similar to the other supply equations but slightly lower long-run elasticities because of higher elasticities of adjustment.

**ESTIMATION OF HARDWOOD LUMBER DEMAND**

The estimated aggregate demand relationship is as follows:

\[(4.3) \ Q_{HLD_t} = f(Q_{HLD_{t-1}'}, W_{PO_t}, P_{HL_{t-1,2}'}, P_{LM_{t-1,2}'}, R_{t-1,2}', T)\]

where:

- \(Q_{HLD_t}\) = Quantity of lumber demanded (in million bf) in time period \(t\),
- \(Q_{HLD_{t-1}}\) = Quantity of lumber demanded in \(t-1\),
- \(W_{PO_t}\) = Weighted price index of output (in nominal terms 1967 = 100) in time period \(t\),
- \(P_{HL_{t-1,2}}\) = Two year moving average of price index for hardwood lumber, lagged on year (price index in nominal terms 1967 = 100),
- \(P_{LM_{t-1,2}}\) = Two year moving average of wage rates in manufacturing, lagged one year (wage rate in nominal dollars per hour),
- \(R_{t-1,2}\) = Two year moving average of interest rate on 4 to 6 month prime commercial paper, lagged one year,
- \(T\) = Time trend(1959 = 1, and then increasing at one unit per year).

The results of the estimated aggregate hardwood lumber demand equation are presented with the long-run elasticity estimates in Table 8. The equations was estimated in double log form, thus the estimated coefficients of the price variables represent short-run elasticities.
### TABLE 8 Estimated Aggregate Demand Demand for Hardwood Lumber for the United States, 1960-1978

<table>
<thead>
<tr>
<th></th>
<th>Estimated Results</th>
<th>Long Run Elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>11.38 (1.73)a</td>
<td>na</td>
</tr>
<tr>
<td>Lagged Quantity</td>
<td>.263 (.147)b</td>
<td>na</td>
</tr>
<tr>
<td>2 Year Moving Average of Price Index of Lumber, Lagged One Year</td>
<td>-.939 (.267)a</td>
<td>-1.27</td>
</tr>
<tr>
<td>Output</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price Index</td>
<td>1.80 (.539)a</td>
<td>2.44</td>
</tr>
<tr>
<td>2 Year Moving Average of Wage Rate, Lagged One Year</td>
<td>-1.30 (.403)a</td>
<td>-1.76</td>
</tr>
<tr>
<td>2 Year Moving Average of Interest Rate, Lagged One Year</td>
<td>-.100 (.059)b</td>
<td>-.136</td>
</tr>
<tr>
<td>Time</td>
<td>.343 (.076)a</td>
<td>na</td>
</tr>
<tr>
<td>R-Square</td>
<td>.915</td>
<td>na</td>
</tr>
<tr>
<td>F-Value</td>
<td>19.8</td>
<td>na</td>
</tr>
</tbody>
</table>

Note: The models is in double log or multiplicative form, therefore all coefficients represent short run point elasticities.

a: significant at the .01 level
b: significant at the .05 level
c: significant at the .10 level
d: significant at the .15 level
na: not applicable
The elasticity of adjustment for the equations is one minus the coefficient of the lagged quantity demanded. The long-run elasticities were calculated by dividing the short-run elasticities by the elasticity of adjustment.

Aggregate demand was estimated as a function of lagged quantity, current price of output, the average prices of lumber, wage rate and average rate of interest in the previous two years and time. Price of output was the weighted sum of the price of furniture and the price of finished producer goods. The rate of interest of 4 to 6 month prime commercial paper was used to calculate the moving average of interest rates.

The lagged two year moving average associated with price of lumber and prices of other inputs was included into the demand relationship because furniture and pallet manufacturers reaction time to changes in input prices was believed to be between one and two years. The length of this reaction time is based on extensive interviews with hardwood lumber buyers and sellers.

Price of energy was excluded in this specification after numerous attempts to include this variable yielded inconsistent parameter estimates of this and other variables. One possible cause of these estimation problems is that many demanders of hardwood lumber use scrap lumber and sawdust as boiler fuel, and, in turn, produce electricity used by the firm.

Quantity demanded was estimated to be inversely related to lagged lumber price, wage rate and interest rates, and to be positively related
to the current output price. The results in Table 8 are consistent with a priori expectations with respect to the signs of the estimated coefficients. The coefficient for lagged quantity was positive and less than 1, indicating that adjustment to changes in input and output price do not fully occur in the time frame of the model specification.

The overall fit of the aggregate demand model is good, with an $R^2$ of .91. All coefficients for the predetermined variables are significant at the 1 percent level, except for the moving average of interest rates which is significant at the 5 percent level.

The results indicate that hardwood lumber demand reacts more slowly to changes in prices of inputs and outputs than does hardwood lumber supply. This statement is based on the relative size of the coefficient of adjustment of the demand equation (.73), versus the coefficient of adjustment for the aggregate supply equation of .90. The results also indicate that current lumber demand is substantially affected by the current price of output. The long-run elasticity associated with the current price of output is 2.44, while the short-run elasticity is 1.80. This high price elasticity of output is consistent with the observation that the quantity of hardwood lumber demanded tends to move with the economy. When the economy is in a recession, output price tends to be depressed so that the quantity of hardwood lumber demanded is low, but when economic activity increases, output prices rise and the quantity of hardwood lumber demanded increases.

The estimated short-run price elasticity of demand for lumber is -.94, which indicates that the price elasticity of demand for lumber is
greater than long-run price elasticity of supply of lumber. The short-
run elasticity of labor price is elastic at -1.3, meaning that a one
percent increase in lagged labor costs causes a 1.3 percent decrease in
hardwood lumber demand two years henceforth.

The long-run elasticity of hardwood demand with respect to a two
year moving average of lagged interest rate is -.13. This elasticity is
about two-thirds the size of the elasticity associated with the same
variable in the supply models. Therefore, the responsiveness of
hardwood lumber supply to changes in interest rates is greater than is
the responsiveness of hardwood lumber demand.

ESTIMATION OF HARDWOOD LUMBER PRICE

Estimates of the coefficients of the aggregate hardwood lumber
price equation are presented in this section. The specification of the
price equation is:

(4.4) \[ PHL_t = h(PHL_{t-1}, QHLD_t, QHLE_t, INV_t) \]

and

(4.5) \[ INV_t = INV_{t-1} + QHLS_t - QHLD_t - QHLE_t \]

where:

- \( PHL_t \) = Price of hardwood lumber (in nominal terms 1967 =
100) time period \( t \),
- \( PHL_{t-1} \) = Price of hardwood lumber in time period \( t-1 \),
QHLD<sub>t</sub> = Aggregate quantity of domestic hardwood lumber demanded (million bf) by domestic demanders in time period t,

QHLE<sub>t</sub> = Quantity of domestic hardwood lumber exported (million bf) in time period t,

INV<sub>t</sub> = Quantity of hardwood lumber held in inventory (million bf) during period t,

INV<sub>t-1</sub> = Quantity of hardwood lumber held in inventory in time period t-1,

QHLS<sub>t</sub> = Quantity of hardwood lumber supplied (million bf) in time period t.

The results of the ordinary least square estimates are presented on Table 9. The equation was estimated in double log form, and the estimated coefficients represent price flexibilities. Price of hardwood lumber was estimated as a function of lagged price of hardwood lumber, quantity demanded, quantity exported and year end inventories.

The results in Table 8 are consistent with a priori expectations since they correspond to theoretical considerations. Hardwood lumber price was estimated to be positively related to quantity demanded and quantity exported, while being inversely related to inventories. The overall fit of the hardwood lumber price equation is quite good with an $R^2$ of .96. All coefficients were significant at the 1 percent level, except for the quantity demanded variable which was significant at the 5 percent level.

The coefficient associated with lagged price can be considered a coefficient of expectation. The rather high value of the coefficient of expectation (.91) indicates that price expectations affect current price to a large degree. The results also indicate that export demand for
TABLE 9  Estimated Price Equation for Hardwood Lumber in the United States, 1960-1978

<table>
<thead>
<tr>
<th></th>
<th>Estimated Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.987</td>
</tr>
<tr>
<td></td>
<td>(2.78)</td>
</tr>
<tr>
<td>Lagged Price</td>
<td>0.910</td>
</tr>
<tr>
<td></td>
<td>(0.110)a</td>
</tr>
<tr>
<td>Quantity Demanded</td>
<td>0.327</td>
</tr>
<tr>
<td></td>
<td>(0.247)c</td>
</tr>
<tr>
<td>Quantity Exported</td>
<td>0.146</td>
</tr>
<tr>
<td></td>
<td>(0.086)b</td>
</tr>
<tr>
<td>Inventory</td>
<td>-0.365</td>
</tr>
<tr>
<td></td>
<td>(0.156)a</td>
</tr>
<tr>
<td>R-Square</td>
<td>0.960</td>
</tr>
<tr>
<td>F-Value</td>
<td>77.6</td>
</tr>
</tbody>
</table>

Note: The model is in double log or multiplicative form, therefore all coefficients represent point elasticities.

a: significant at the .01 level
b: significant at the .05 level
c: significant at the .10 level
d: significant at the .15 level
domestic hardwood lumber significantly influences domestic price. Although the price flexibility of export demand is only .15, the 300 percent increase in export demand during the seventies has contributed to the increase in the price of lumber during this period. Quantity of hardwood demanded domestically also influences hardwood lumber price, but, since the year to year percentage change in the quantity demanded domestically is low, the actual affect of domestic demand on hardwood lumber price has not been as great during the 70's as has the affect of export demand.

Changes in hardwood lumber inventories also account for year to year fluctuations in hardwood lumber price. The inventory flexibility of -.37 indicates that a one percent increase in inventories cause a .37 percent decrease in lumber price.

**IMPLICATIONS**

The hardwood lumber market model is composed of the aggregate supply, demand and price equations presented in the last three sections of this chapter. The specific equations of the aggregate U.S. model include the aggregate supply equation the aggregate demand equation and the price equation. The structure of the model is recursive with the causal flow originating from the demand relationship. The causal flow originates from the demand equation since quantity demanded is a function of predetermined endogenous and exogenous variables. This structure differs from the typical recursive models developed for agricultural markets in which the causal flow originates from the supply relationship.
The results of the demand equation indicates that hardwood lumber users do not start to react to changes in hardwood lumber prices or change in price of other inputs until one or two years after these changes have occurred. However, the supply of hardwood lumber reacts almost immediately to changes in lumber prices. A relatively low price of hardwood lumber stimulates an increase in quantity demanded one or two years later. The increase in quantity demanded causes inventories to decrease and price to increase. The increase in price encourages hardwood lumber producers to increase their production and also attracts new producers to enter the market. However, increases in price will also cause quantity demanded to decrease one or two years later. Increases in quantity supplied and decreases in quantity demanded causes lumber prices to decrease. Thus the structure of the hardwood lumber market can be thought of as a reverse cobweb.

A problem associated with cobweb type markets is the amount of uncertainty created by constant fluctuations of demands and supplies and subsequent fluctuations in price. Uncertainty may discourage current and potential demanders from committing themselves to future use of hardwood lumber while current and potential suppliers may be discouraged from purchasing expensive equipment and incorporating new technology.

Stability conditions for the reverse cobweb structure are the same as for the traditional cobweb structure. The estimated market model will be stable if the absolute value of lagged price elasticity of demand times the price flexibility of demand is less than one. The absolute value of the product of these estimated parameters is .350,
therefore, the estimated hardwood lumber market model is stable.

The results of the estimated aggregate supply and demand relationships indicate that wage rates are an extremely influential factor in the hardwood lumber market. In both the demand and supply relationships the labor price elasticities were substantially greater than the price elasticities of any of the other inputs. These results indicate that hardwood lumber demanders and suppliers must address labor productivity problems in order to control production costs. Since lumber demanders and suppliers pay many of their production workers at or near the minimum wage rate, increases in the minimum wage will adversely affect the demand and supply of hardwood lumber. The affect of increased wage rates can be seen in the following example. The estimated short-run labor price elasticity of supply was -0.76 while labor price elasticity of demand was -1.3. If wage rate was to increase by one percent, then quantity supplied would initially decrease by 0.76 percent and quantity demanded would decrease by 1.3 percent. Since quantity demanded decreases more than quantity supplied, price would decrease which would cause supply to decrease and demand to increase. After all repercussions of a one percent increase in wage rate have taken place, quantity demanded decreases 1.22 percent, quantity supplied decreases by 1.14 percent, and price decreases by 0.41 percent.\(^5\)

Interest rates were shown to have a negative influence on both hardwood lumber demand and supply, but, the elasticities of demand and supply with respect to interest rates are low when compared to all other input price elasticities. The net affects of a one percent increase in
interest rate are a .17 percent reduction in quantity demanded, a .19 percent reduction in quantity supplied, and a .06 percent increase in price. However, higher interest rates indicate a higher rate of inflation and, therefore, indicate increasing production costs and usually decreased production.

Output price of the demanders of hardwood products is another influential variable affecting the hardwood lumber market. The price elasticity of demand of output is quite elastic at 1.8. The net affect of a 1 percent increase in output price, after all repercussions have been taken into consideration, leads to a .93 percent increase in quantity demanded, .87 percent increase in quantity supplied, and a 1.19 percent increase in lumber price.

The average of current and lagged price of stumpage is also an influential variable in the aggregate supply equation. However, the calculated elasticity for stumpage cost was a little over half the size of the elasticity of wage rate. The effect of a 1 percent increase in the price of stumpage, after all repercussions have taken place, is to a .08 percent decrease in the quantity of lumber supplied, a .28 percent decrease in quantity of lumber demanded, and a .54 percent increase in the price of lumber. An implication of these results is that increasing inventories and a resulting decrease in price of hardwood sawtimber result is not a sufficient stimulus for increase production of hardwood lumber. Rather lumber production is a function of a number of factors with wage rates, labor productivity and output price being much more influential factors than stumpage cost.
Although the short-run price flexibility of hardwood lumber export was near .15, the long-run affects of lumber exports on lumber price are much less because the increase in lumber price caused by exports will also cause supply of lumber to increase. After all ramifications have been taken into consideration, a one percent increase in hardwood lumber exports lead to a .02 percent increase in quantity supplied, a .04 percent decrease in quantity demanded, and a .03 percent increase in price of hardwood lumber. The implication of these results is that the long-run impact of lumber exports on price of hardwood lumber are one fifth the magnitude of the sort run impacts.
1 An attempt was made to estimate maple supply for Eastern, Northeastern and Southeastern United States. Many attempts at estimating these models using ridge regression and OLS techniques resulted in poorly fitting models with insignificant coefficients. The problem with the maple models probably stems from the measurement error associated with estimating maple production. Another reason for the poor results is lack of a proper surrogate for a weighted price of maple lumber and weighted price of maple stumpage.

2 The states included in the Northeastern region are Maine, New Hampshire, Massachusetts, Connecticut, Vermont, Rhode Island, New York, New Jersey, Ohio, Indiana, Illinois, Michigan, Wisconsin, Minnesota, Iowa, Missouri, Kansas, and Nebraska. The states included in the Southeastern region are Virginia, West Virginia, North Carolina, South Carolina, Delaware, Maryland, Georgia, Florida, Kentucky, Tennessee, Alabama, Mississippi, Arkansas, Louisiana, Oklahoma and Texas. The states included in the Eastern region include all states in the Northeastern and Southeastern regions.

3 Preliminary analysis of price of National Forest oak stumpage and oak stumpage on private lands in Louisiana resulted in high correlation between these two price series. In this analysis, National Forest stumpage was found to be a multiple of stumpage on privately own land.

4 Stability of the model refers to whether or not a change in an exogenous variable will cause the system to converge to a new equilibrium solution, or continually diverge from equilibrium.

Waugh's discussion of the traditional cobweb model considered a price and supply equation. This system was as follows:

Traditional System

\[
\begin{align*}
    p_t &= -a q_s \quad t \\
    q_{st+1} &= b p_t = -ba q_s
\end{align*}
\]

where:

- \( p_t \) = price period \( t \)
- \( q_s \) = quantity produced in time period \( t \)
- \( q_{st+1} \) = quantity produced in time period \( t+1 \)

From this basic model Waugh demonstrates that the system will converge if the absolute value of the product \( ab \) is less than 1.
The system developed in the current study can be written as follows:

Alternative System

price

\[ p_t = a qd_t \]

lagged output

\[ qd_{t+1} = -b p_t = -ba qd_t \]

where:

- \( p_t \): price period \( t \)
- \( qd_t \): quantity demanded in time period \( t \)
- \( qd_{t+1} \): quantity demanded in time period \( t+1 \)

The alternative system is just the reverse of the system discussed by Waugh, and can be decomposed into an identical algebraic expression, except lagged quantity is quantity demanded instead of quantity supplied. Therefore, the stability conditions of the two system are the same.

5 The percentage change figures used throughout this section were calculated through the use of a computer program shown in Appendix C. Percentage change in quantity demanded does not equal percentage change in quantity supplied because of changes in inventories.
CHAPTER V
DEMAND FOR LUMBER BY WOOD FURNITURE MANUFACTURERS

Furniture manufacturers' demand for hardwood lumber of different species and different grain patterns are investigated in this chapter. The analysis is based on wood usage data collected from wood furniture manufacturers. The data collection procedure is discussed in the first part of this chapter. The second part is concerned with the estimation of the models and analysis of the empirical results. The final section discusses the implications of the statistical analyses.

DATA COLLECTION

The initial step of the data collection process entailed developing a list of wood furniture manufacturers from the directories of the Southern Furniture Manufacturers Association and the National Association of Furniture Manufacturers. The survey was confined to the states of North Carolina, Virginia, Tennessee and South Carolina because of limited resources, particularly travel funds. It was felt that since 45 percent of the wood furniture manufacturers in the United States were located in these four states, a survey of manufacturers in these states would yield the necessary data needed to analyze furniture manufacturers' demands for various species of lumber.

Furniture producers were initially screened to determine if they were wood furniture producers by consulting the directories and knowledgeable people in the field. After a list of firms was developed,
appointments were made with lumber buyers and other personnel in order to solicit wood use data. After several conversations with lumber buyers and lumber brokers, it was decided that only larger firms which used several species of exterior lumber were appropriate for the analysis. Smaller firms which used one or two species of lumber in exposed parts of their furniture line(s) tended not to substitute lumber of different species.

The data base used to estimate the empirical models consisted of manufacturers who: (1) used at least three different species for face or exterior lumber in several lines of furniture and, (2) whose main output was wood furniture. Manufacturers who produced both wood and upholstered furniture were asked to give wood use information for their wood furniture plant(s). Excluding smaller manufacturers from the survey should not bias the general implications drawn from the results to any great extent because 10 percent of the wood furniture manufacturers use 75 percent of the material used in this industry.¹ Therefore, the larger manufacturers account for approximately 75 percent of the wood used by the entire wood furniture industry.

Since most firms did not keep long term records on their wood use by species, firms were asked to provide data for the period 1974-1978. This time span was picked because it appeared that many firms could supply such data. However, many firms had no record of their past lumber use, while others said that to develop such data from their records would be very costly. Out of the 28 firms contacted which met the above criteria, 11 firms provided data for the years 1974-78. Since
the actual analysis of the data was done in the spring and summer of
1980, the 11 firms who had previously supplied data were asked to also
supply wood use data for 1979. Nine of these firms responded with the
1979 data.

FURNITURE MANUFACTURERS' DEMANDS

The estimates of furniture manufacturers' demands for oak, maple
and poplar lumber, as well as demands for all open grained and closed
grained lumber by furniture manufacturers are presented and compared in
this section. All the demand equations were estimated using the cross
sectional time series technique developed by Parks (23). The reasons
for using a generalized least square algorithm rather than ordinary
least square, and a discussion on the Parks method are presented in
Appendix D.

The general form of all the demand equations that were estimated is
as follows:

\[(5.1) \ Q_{HLD, jk, t} = g(\ Q_{HLD, jk, t-1}, \ PHL_{jk, t-1}, \ POL_{jk, t-1}, \ WPWF_t)\]

where:

\[Q_{HLD, jk, t} = \text{Quantity of hardwood lumber (in thousand bf) of}
\text{species j demanded by furniture manufacturer k in}
\text{time period t,}\]

\[Q_{HLD, jk, t-1} = \text{Quantity of hardwood lumber of species j demanded}
\text{by furniture manufacturer k in time period t-1,}\]
PHL_{jk,t-1.5} = Price index of lumber (in nominal terms 1974 = 100) of species j, lagged one and one half years (assumed constant across firms),

POL_{jk,t-1.5} = Price index of substitute lumber (in nominal terms 1974 = 100) for species j used by firm k lagged one and one half years,

WPWF_t = Wholesale price index of wood furniture (in nominal terms 1974 = 100) in time period t.

The quantity demanded of a particular species of lumber, or lumber of a particular grain pattern, was estimated as a function of lagged quantity, price index of the lumber lagged 1\frac{1}{2} years, price index of substitute lumber lagged 1\frac{1}{2} years and current price of wood furniture. The price indexes were developed from prices of One Common lumber reported in the Hardwood Market Report. Since the length of the specific lag specification for lumber price was expected to be between one and two year, three lag specifications were tried. The 1\frac{1}{2} year specification resulted in smaller standard errors than either the one year or two year lag structure.

The results of the ordinary least square (OLS) estimates are presented in Table 10, while the cross-sectional, time-series (CSTS) estimates are presented in Table 11. The standard errors associated with almost all the parameters were reduced as a result of using the Parks estimation procedure. Furthermore, the magnitude of the coefficients do not differ significantly between the OLS estimates and the CSTS estimates, except in the case of the maple model. Although it is sometimes difficult to evaluate the validity of CSTS estimates, the decrease in standard error without a radical change in the magnitude of
### TABLE 10 Ordinary Least Squares Results of Wood Furniture Manufacturers' Demand for Hardwood Lumber, by Species, 1975-1979

<table>
<thead>
<tr>
<th></th>
<th>All Lumber</th>
<th>Open Grained Lumber</th>
<th>Oak Lumber</th>
<th>Closed Grained Lumber</th>
<th>Maple Lumber</th>
<th>Poplar Lumber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-5337</td>
<td>-3124</td>
<td>-3832</td>
<td>-3140</td>
<td>-2318</td>
<td>-1487</td>
</tr>
<tr>
<td></td>
<td>(5737)</td>
<td>(4032)</td>
<td>(3139)</td>
<td>(2929)</td>
<td>(3254)</td>
<td>(2137)</td>
</tr>
<tr>
<td>Lagged Quantity</td>
<td>.967</td>
<td>.959</td>
<td>.857</td>
<td>.963</td>
<td>.816</td>
<td>1.006</td>
</tr>
<tr>
<td></td>
<td>(.032)a</td>
<td>(.043)a</td>
<td>(.065)a</td>
<td>(.062)a</td>
<td>(.179)a</td>
<td>(.039)a</td>
</tr>
<tr>
<td>Price Index for Lumber</td>
<td>-1566</td>
<td>-3802</td>
<td>-3261</td>
<td>-547</td>
<td>7924</td>
<td>-856</td>
</tr>
<tr>
<td></td>
<td>(6054)</td>
<td>(3460)d</td>
<td>(2686)d</td>
<td>(501)a</td>
<td>(6072)</td>
<td>(1398)</td>
</tr>
<tr>
<td>Price Index for Substitute Lumbers</td>
<td>na</td>
<td>2319</td>
<td>5964</td>
<td>-21.8</td>
<td>-62.8</td>
<td>-1164</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(3534)</td>
<td>(2291)a</td>
<td>(2098)</td>
<td>(1367)</td>
<td>(1864)</td>
</tr>
<tr>
<td>Price Index for Furniture</td>
<td>44.0</td>
<td>27.3</td>
<td>5.03</td>
<td>23.6</td>
<td>-1.43</td>
<td>20.9</td>
</tr>
<tr>
<td></td>
<td>(32.6)d</td>
<td>(27.8)</td>
<td>(29.1)</td>
<td>(18.1)c</td>
<td>(24.6)</td>
<td>(14.8)c</td>
</tr>
<tr>
<td>R-Square</td>
<td>.958</td>
<td>.935</td>
<td>.905</td>
<td>.911</td>
<td>.599</td>
<td>.954</td>
</tr>
<tr>
<td>F-Value</td>
<td>309</td>
<td>127</td>
<td>59.6</td>
<td>64.4</td>
<td>7.50</td>
<td>183</td>
</tr>
<tr>
<td>Degrees of Freedom</td>
<td>40</td>
<td>35</td>
<td>25</td>
<td>25</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>Mean Quantity, Mbf</td>
<td>16148</td>
<td>7669</td>
<td>5470</td>
<td>3224</td>
<td>1590</td>
<td>3300</td>
</tr>
</tbody>
</table>

Note: All models are in linear variates.

a: significant at the .01 level
b: significant at the .05 level
c: significant at the .10 level
d: significant at the .15 level
na: not applicable
TABLE 11  Cross Sectional Time Series Results for Wood Furnitures Manufacturers' Demand for Hardwood Lumber, 1975-1979

<table>
<thead>
<tr>
<th></th>
<th>All Lumber</th>
<th>Open Grained Lumber</th>
<th>Oak Lumber</th>
<th>Closed Grained Lumber</th>
<th>Maple Lumber</th>
<th>Poplar Lumber</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-6569</td>
<td>-4219</td>
<td>-3398</td>
<td>-3096</td>
<td>-902</td>
<td>1896</td>
</tr>
<tr>
<td></td>
<td>(1400)a</td>
<td>(861)a</td>
<td>(821)a</td>
<td>(934)a</td>
<td>(681)c</td>
<td>(1051)b</td>
</tr>
<tr>
<td>Lagged Quantity</td>
<td>.994</td>
<td>1.01</td>
<td>.941</td>
<td>.898</td>
<td>.964</td>
<td>1.024</td>
</tr>
<tr>
<td></td>
<td>(.006)a</td>
<td>(.011)a</td>
<td>(.019)a</td>
<td>(.070)a</td>
<td>(.058)a</td>
<td>(.048)a</td>
</tr>
<tr>
<td>Price Index for Lumber</td>
<td>-1566</td>
<td>-3931</td>
<td>-3580</td>
<td>-627</td>
<td>-1282</td>
<td>-1163</td>
</tr>
<tr>
<td></td>
<td>(352)a</td>
<td>(575)a</td>
<td>(658)a</td>
<td>(84.5)a</td>
<td>(638)b</td>
<td>(588)b</td>
</tr>
<tr>
<td>Price Index for Substitute Lumber</td>
<td>na</td>
<td>4096</td>
<td>3576</td>
<td>776</td>
<td>256</td>
<td>-849</td>
</tr>
<tr>
<td></td>
<td>(685)a</td>
<td>(814)a</td>
<td>(414)b</td>
<td>(144)b</td>
<td>(435)b</td>
<td></td>
</tr>
<tr>
<td>Price Index for Furniture</td>
<td>45.8</td>
<td>23.6</td>
<td>17.4</td>
<td>20.3</td>
<td>13.2</td>
<td>22.7</td>
</tr>
<tr>
<td></td>
<td>(11.8)a</td>
<td>(5.10)a</td>
<td>(4.78)a</td>
<td>(6.29)a</td>
<td>(4.75)a</td>
<td>(5.12)a</td>
</tr>
<tr>
<td>R-Square</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
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<td>na</td>
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<tr>
<td>F-Value</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Degrees of Freedom</td>
<td>40</td>
<td>35</td>
<td>25</td>
<td>25</td>
<td>20</td>
<td>35</td>
</tr>
<tr>
<td>Mean Quantity</td>
<td>16148</td>
<td>7669</td>
<td>5470</td>
<td>3224</td>
<td>1590</td>
<td>3300</td>
</tr>
<tr>
<td>M bf</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: All models are in linear variates.

a: significant at the .01 level  
b: significant at the .05 level  
c: significant at the .10 level  
d: significant at the .15 level  
na: not applicable
the estimated coefficients is extremely encouraging. Such results indicate that only a change in statistical efficiency has occurred as a result of using the Parks procedure.

The calculated elasticities of the various demand equations are presented in table 12. All elasticity estimates were calculated from the CSTS results. Since both the OLS and the CSTS estimates were calculated from data collected across cross sections and time series, the estimated elasticities are not really representative of either the short or long-run. Therefore, these estimates should be used only to compare the differences in elasticities between lumber of different species and grain patterns.

The own price elasticity for all lumber demanded by the sample of furniture manufacturers is -0.09 which is quite low. This is not surprising since wood furniture manufacturers must use wood to produce wood furniture. The furniture price elasticity is also quite low, 0.49, when compared with the demand equations for the different species.

The own price elasticity of demand for the open grained lumber was -0.53, while the own price elasticity of demand for oak was -0.65. This is expected a priori since own price elasticity of demand of an aggregate is less than the price elasticities of demand of the individual parts of the aggregate. The estimated cross price elasticity for oak lumber was 0.74 compared to 0.57 for all open grained lumber. This again conforms to a priori expectations since the cross elasticity of an aggregate demand is expected to be lower than the cross elasticity of a component of the aggregate. The furniture price elasticity for
<table>
<thead>
<tr>
<th>Model</th>
<th>Own Price Elasticity</th>
<th>Cross Price Elasticity</th>
<th>Furniture Price Elasticity</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Lumber</td>
<td>-.087</td>
<td>na</td>
<td>.488</td>
</tr>
<tr>
<td>Open Grain Lumber</td>
<td>-.525</td>
<td>.566</td>
<td>.528</td>
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<tr>
<td>Oak Lumber</td>
<td>-.654</td>
<td>.743</td>
<td>.550</td>
</tr>
<tr>
<td>Closed Grain Lumber</td>
<td>-.265</td>
<td>.243</td>
<td>1.08</td>
</tr>
<tr>
<td>Maple Lumber</td>
<td>-.867</td>
<td>.171</td>
<td>1.43</td>
</tr>
<tr>
<td>Poplar Lumber</td>
<td>-.295</td>
<td>-.282</td>
<td>1.18</td>
</tr>
</tbody>
</table>

Note: All elasticities were calculated at the means using the parameter of the cross sectional time series analysis

na: not applicable
open grained wood was .53 and .55 for oak indicating that these elasticities are very close to one another.

The own price elasticity for the closed grained lumber demand was -.27 while the own price elasticity for maple lumber demand was -.87. As in the case of the open grained lumber, the own price elasticity of the aggregate was lower than the own price elasticity for a component of the aggregate. However, the cross price elasticity of maple lumber demand is lower than the cross price elasticity for closed grained lumber demand. Since the cross price elasticity of demand for maple lumber (.17) is lower than the cross elasticity of demand for other closed grained lumber (.28), the cross price elasticities of the demand for other closed grained woods should exceed .28. The furniture price elasticity of demand for closed grained lumber was higher than the furniture price elasticity of open grained lumber. This indicates that furniture prices affect the demands for closed grained lumber more than they affect the demand for open grained lumber.

The own price elasticity of poplar demand is -.30, indicating that poplar demand is less elastic than the demands for open or closed grained lumber. The cross price elasticity for poplar lumber demand is -.28, indicating poplar is a complement to other lumber and not a substitute. Both the low own price elasticities and the negative cross price elasticity are plausible in the case of poplar lumber since poplar is used for interior parts. The demand for less expensive interior lumber used with all types of exterior lumber should be less elastic than the more expensive exterior lumber. Furthermore, since poplar is
used in the production of interior parts, the demand for poplar lumber should increase when the demand for other lumber increases, therefore, poplar would be a complement to other lumber.

IMPLICATIONS

One major implication of the statistical results presented in this chapter is that wood furniture manufacturers' demands for hardwood lumber, as a whole, are quite inelastic with respect to the price of hardwood lumber. However, these manufacturers' demands for lumber of specific species or groups of species are much more price elastic than the demand for all lumber. Of the individual species and species groups open grained, oak and maple lumber are more price elastic than poplar and closed grained lumber.

Furniture manufacturers' demand for closed grained lumber are relatively inelastic with respect to the price of closed grained lumber and the price of substitute lumber, but are relatively elastic with respect to price of output. The implications of these results are that the demands for some of the more traditional species of furniture lumber, such as cherry and mahagony, are not greatly effected by price of lumber of these and substitute species, but are influenced by the price of wood furniture.

Maple lumber demand is different from the lumber demand of other closed grained species in that maple demand is relatively price elastic. However, demand for maple lumber is similar to the demand for closed grained lumber in that cross price elasticity is relatively low and
furniture price elasticity is relatively elastic. The implications of these results are that maple lumber demand is greatly effected by the price of maple lumber and the price of wood furniture.

The estimated results of the demand for open grained lumber indicates little difference between own price elasticity, cross price elasticity, and furniture price elasticity. The implications of these results are that the price of open grained lumber, the price of lumber of substitute species and the price of furniture have about an equal effect on the demand for lumber of the open grained species.

Oak lumber demand is different from the demand for all open grain species in that the absolute value of the cross price and own price elasticity of demand are up to 35 percent larger than the furniture price elasticity. However, the furniture price elasticity for oak lumber is very close to the furniture price elasticity for all open grained lumber. The implications of these results are that the demand for oak lumber is more responsive to changes in the price of oak lumber and lumber of other species than it is to changes in the price of furniture.

The estimated demand for poplar lumber resulted in a relatively inelastic own price elasticity and a relatively elastic furniture price elasticity. The negative cross price elasticity of the poplar demand equation indicates that poplar lumber is used in conjunction with lumber of other species, rather than being a substitute for lumber of other species. The implications of the estimated results are that poplar lumber is only slightly effected
by poplar lumber price, but greatly affected by the price of wood furniture.
FOOTNOTES


2 Open grained lumbers include oak, ash, elm, pecan, hackberry and other lumbers of wide grain. Closed grained lumbers include maple, cherry, mahagony, beech, gum and other lumber with a tight grain structure.

3 The variable representing price of substitute lumbers in the oak equation was calculated as the weighted price index of ash, pecan, elm, hackberry, maple and white pine lumber. Lumber of these species have some characteristics which allow them to be substituted for oak. The first three species were chosen because they are open grain species. Maple was included because it and oak are intermediate priced lumber. White pine was included because it and oak are both used in heavy, over designed, furniture. The cross price variable for open grained lumber contained the weighted price index of all other lumbers.

4 The variable representing price of substitute lumbers in the maple equation was calculated as the weighted price index of cherry, gum, and oak lumber. It was felt that lumber of these species had some characteristics which allowed them to be substituted for maple lumber. Cherry and gum are closed grained lumber with some similar characteristics of maple lumber, while oak and maple lumber are two intermediately priced lumbers. The price of substitute lumbers in the closed grained equation was the weighted price index of all other lumbers.

5 It should be noted that the data base used in the estimation of the poplar demand equation did not contain any promotional furniture producers. Promotional furniture producers use poplar lumber in exterior parts and therefore may substitute poplar lumber for sweet gum, black gum or another inexpensive wood which can be embossed with a pattern.
CHAPTER VI
MODEL EVALUATION AND PROJECTIONS

Since 1900 the hardwood lumber market has remained relatively stable with respect to quantities demanded and supplied, while the price of hardwood lumber has trended with the wholesale price index over the last 30 years. There have been year to year variations in demand, supply and price of hardwood lumber, however, the hardwood lumber market has always adjusted back to its seemingly steady state equilibrium after short term shocks have been absorbed by the market system.

The important question raised by the above discussion is will the hardwood market continue to remain stable in the future? The purpose of this chapter is to address these questions and to present projections for the demand, supply and price of hardwood lumber to the year 2005.

The remainder of this chapter will be presented in two sections. The first is an evaluation of the market model presented in Chapters IV. The second section is a presentation of projections for the year 2005 under four selected senarios.

MODEL EVALUATION

The predictive ability of the supply demand and price equations are presented in Charts 1, 2 and 3. The predictive ability of each equation will be evaluated in the subsequent paragraphs.

The supply equation exhibited in Chart 1 performed extremely well, catching 5 of the 6 turning points which occurred during the modeling
CHART 1 OBSERVED VS PREDICTED FOR QUANTITY OF HARDWOOD LUMBER SUPPLIED 1961-1978
CHART 2 OBSERVED VS PREDICTED FOR QUANTITY OF HARDWOOD LUMBER DEMANDED 1961-1978
CHART 3 OBSERVED VS PREDICTED FOR PRICE OF HARDWOOD LUMBER 1961-1978

PRICE INDEX 1967 = 100


TIME

+ OBSERVED
X PREDICTED

VS TIME
period. The one missed turning point occurred when the equation showed an upturn in 1967 when the actual upturn occurred in 1968. In conclusion, the supply equation's predictive ability is excellent.

The demand equation (Chart 2) performed well catching 50 percent of the turning points which occurred in the data base. The ability of the equation to catch major turning points was excellent. Not only were the turning points in 1966, 1967, 1969 and 1975 predicted by the demand equation, but the magnitude of these changes were also predicted quite well.

The majority of turning points missed by the estimated demand equation occurred during the period between 1970 and 1973. During this period the quantity demanded fluctuated by changing directions 3 times. The fact that these fluctuations were small in magnitude and occurred at a rapid rate is a good explanation why the predicted turning points lagged the actual turning points by one year. Since the estimated demand equation seems only to have difficulties in predicting minor turning points, and has no problem in predicting major turning points, the predictive abilities of this equation must be considered good to excellent.

The ability of the price equation (Chart 3) to account for general price trends is good, but the ability of this equation to catch turning points is poor. The inability of the price equation to catch turning points can be attributed to the influence of lagged price. The high estimate for the coefficient of expectation in equation 4.3 causes the estimated turning points to occur a year after the actual turning point.
However, the general ability of the price equation to account for price trend implies that this equation can be used for long term price forecasts with few difficulties.

Theil's (30) $U_1$ statistic is a general indicator of the predictive ability of an econometric equation. A $U_1$ value of zero indicates a perfect forecasting equation while a value under 1 implies that the equation has good predictive abilities. The $U$ statistic can be used to evaluate the relative predictive abilities of alternative models based on the relative magnitude of $U_1$.

The estimates of the $U_1$ statistic was .34 for the supply equation, .47 for the demand equation and .61 for the price equation. The relative magnitudes of these statistics indicate that all the equations have good predictive qualities. The supply model has the best predictive qualities, while the price model is the poorest of the three. These results support the previous evaluation of these three equations.

PROJECTIONS

Projections for hardwood lumber demand, supply and price for the year 2005 are presented in this section. All projections are based on the aggregate demand, supply and price models developed in Chapter IV. Since the demand, supply and price equations were estimated in double log form while using a linear equilibrium constraint, an iterative procedure was used to develop the projections. This procedure was based on the causal flow which exists in the hardwood lumber market and is graphically exhibited on Chart 4. The computer program used to
CHART 4 The Directional Flow for Demand Supply and Price in the Hardwood Lumber Market in the United States

Quantity of Hardwood Lumber Demanded
  dependent on past hardwood lumber prices
  
  Price of Hardwood Lumber
  dependent on quantity of hardwood lumber demanded and inventories

Supply of Hardwood Lumber
  dependent on price of hardwood lumber

Inventories of Hardwood Lumber
  dependent on supply and demand of hardwood lumber
calculate the projection is presented in Appendix D.

Four scenarios were developed assuming different yearly increases in wage rate, stumpage price, output price and technology, and different prevailing rates of interest. Scenarios 1 and 2 assume a mild rate of inflation similar to price increases and interest rates which existed in the early and mid 1970's. Scenario 3 assumes a higher rate of inflation while scenario 4 assumes a very high rate of inflation that has occurred in the early 1980's.

Increases in labor productivity and technology were included in the scenarios through the time trend variables in the demand and supply equations. Since development and implementation of labor saving devices and other technological innovations are directly related to the rate at which wages and other production costs increase, the rate at which the time trend variable increases each year was accelerated for scenarios 3 and 4.

Scenario one represents status quo conditions. Under this scenario output price and wage rate are assumed to increase at 3 percent per year while stumpage prices increase at 2 percent. The prevailing rate of interest under this scenario is 8 percent. Stumpage price is assumed to increase at a lower rate than wages and output price because of the increases in hardwood saw timber inventories that have occurred and are expected to continue to occur in the future.

Increases in technology and labor productivity were introduced into scenario one by increasing the time trend variable by one each year. This rate of increase is identical to the rate of increase of the time
trend variable in the estimated model.

Scenario two represents an optimistic view. The assumptions of this scenario are the same as scenario one, except price of output is expected to increase at 5 percent per year rather than 3 percent per year.

When assuming that output price will increase at a faster rate than labor price, an implied assumption is that prices of products made from hardwood lumber will increase at a faster rate than the general rate of inflation. Price of hardwood lumber products could increase at a faster rate than prices of other goods used by manufacturers or consumed by individuals if the demand for hardwood products shifted upward at a quicker rate than the demands for other goods. An example of this would be if the demand for wood furniture would increase at a faster rate than the demand for automobiles because of changes in consumer habits. Given that all other factors remain constant, this relative increase in demand for wood furniture would cause year to year price increases to be greater for wood furniture than for automobiles.

A pessimistic attitude is assumed in scenario three. Under this scenario price of labor and price of output are expected to increase at 5 percent per year. Stumpage price is assumed to increase at 3 percent per year while interest rate is expected to prevail at 10 percent. Since the price of labor is assumed to increase at a faster rate in this scenario, the rate of increase for the time trend variable was accelerated to 1.5 units per year. The basis of this scenario is the
moderately high rate of inflation which occurred during the late middle 1970's.

The fourth scenario take the super pessimistic attitude that the high rate of inflation which has occurred in the early 1980's will continue for the next 25 years. Price of output and wage rates are assumed to increase at 10 percent per year while stumpage prices increase at 5 percent. The prevailing rate of interest is assumed to be 16 percent while the incremental increase in the time trend variable accelerated to 2 units per year.

Charts 5 and 6 exhibit the resulting time paths for quantity of hardwood lumber demanded and supplied under the four senarios. The time path of hardwood lumber price under the four senarios is exhibited in Chart 7. Chart 8 contains the time paths of hardwood lumber inventory levels under the four senarios. The levels of quantity supplied, quantity demanded, price and inventory of hardwood lumber in the year 2005 under the four senarios are summarized in Table 13.

The results of scenario one show little change in quantity of hardwood lumber demanded or supplied. Under this scenario price increased at 5.4 percent per year while inventories held by lumber suppliers and concentration yards fluctuated, but do not trend upward or downward.

The results of the optimistic scenario are that quantity demanded and supplied would increase by about one third by the year 2005. Hardwood lumber price would increase at 8.0 percent per year. Since
CHART 5 PREDICTED VALUES FOR QUANTITY OF HARDWOOD LUMBER SUPPLIED IN THE YEAR 2005 UNDER FOUR SELECT SCENARIONS

VS TIME

MILLION BOARD FEET

CHART 6 PREDICTED VALUES FOR QUANTITY OF HARDWOOD LUMBER DEMANDED IN THE YEAR 2005 UNDER FOUR SELECT SCENARIOS
CHART 7 PREDICTED VALUES FOR QUANTITY OF HARDWOOD LUMBER PRICE IN THE YEAR 2005 UNDER FOUR SELECT SCENARIOS
CHART 8 PREDICTED VALUES FOR INVENTORIES
OF HARDWOOD LUMBER IN THE YEAR 2005
UNDER FOUR SELECT SCENARIOS

VS TIME

MILLION BOARD FEET
0 500 1000 1500 2000

TIME
<table>
<thead>
<tr>
<th>Scenario</th>
<th>Quantity Produced (million bf)</th>
<th>Quantity Demanded (million bf)</th>
<th>Inventory Levels (million bf)</th>
<th>Price Index (1967=100)</th>
</tr>
</thead>
<tbody>
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<td>1023</td>
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</tr>
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<td>2</td>
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</tr>
<tr>
<td>3</td>
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<td>5075</td>
<td>751</td>
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</tr>
<tr>
<td>4</td>
<td>3446</td>
<td>3110</td>
<td>362</td>
<td>2177</td>
</tr>
</tbody>
</table>
production and usage of hardwood lumber increases under this scenario, the amount of lumber held in inventories will trend upward.

The results of this scenario indicate a decrease in quantity of hardwood lumber demanded and supplied relative to the status quo scenario. The price of hardwood lumber increases at a faster rate than the status quo scenario, but at a slower rate than the under the optimistic scenario. The annual increase in price of hardwood lumber is 7.4 percent while inventories trend downward.

The results from this scenario are devastating. The production and usage of hardwood lumber drop by 50 percent in 25 years, while price sky rockets at 12.1 percent per year. The inventories of hardwood lumber also trend sharply downward under this scenario.
FOOTNOTES

1 Production figures from United States Department of Commerce, Statistical Abstracts of the United States, Historical Statistic, Colonial Times to 1957, Washington D.C.,

Price figures from, Forest Service, United States Department of Agriculture, The Demand and Price Situation for Forest Products, Washington D.C.

2 The year 2005 was picked instead of the year 2000 since a low point in the cobweb cycle occurred in the year 2000. If the year 2000 was used it would be an under representation of the growth which occurred under the various scenarios.

3 It is assumed that wages in sawmilling and wages in manufacturing will increase a 3 percent per year. No distinction was made between these two wage rates because it was felt that in the long run all wage rate tend to increase at nearly the same rate.
CHAPTER VII
SUMMARY AND CONCLUSIONS

The primary purpose of this chapter is to summarize the finding of previous chapters and to discuss the implications of these findings. Future research needs in the area of hardwood lumber markets are discussed in the concluding section of this chapter.

SUMMARY

The hardwood lumber market has historically been stable with respect to quantity demanded, quantity supplied and price. However, during the 1970's the quantity of hardwood lumber supplied and demanded decreased while the price of hardwood lumber increased. The prices of some species preferred by furniture manufacturers has increased by as much as 300 percent during this period. The recent behavior of the hardwood lumber market has caused concern to be expressed by some furniture manufacturers and forest resource planners.

Currently little information is available which would enable lumber demanders and suppliers to evaluate current and future market conditions. The lack of economic information about the structure of the hardwood lumber market hampers market coordination and increases the degree of uncertainty of future market condition facing demanders and suppliers of hardwood lumber. Under conditions of uncertainty optimal resource allocation does not occur, thus reducing the level of profit which individual demanding and supplying firms can obtain.

-100-
Information about the reaction of hardwood lumber demanders and suppliers to changes in hardwood lumber price and other important factors would reduce the degree of uncertainty faced by decision makers. With this information suppliers will be in a better position to anticipate decreases and increases in hardwood lumber demand, thus allowing these suppliers to make better (more profitable) decisions. Likewise, hardwood lumber demanders could make better decisions if they had information concerning the reactions of lumber suppliers to changes in lumber price and other important factors which influence supply. Since hardwood lumber demanders and suppliers can allocate their resources better, relative prices of products produced from hardwood lumber may also decrease. Finally, information on the structure of the hardwood lumber market is a necessary ingredient for the development of long-range plans to insure adequate future supplies of hardwood sawtimber from both public and private lands.

The general objective of this study was to provide information about the the economic structure of the hardwood lumber market. The specific objectives were:

A) To identify the major factors affecting the aggregate demand, supply and price of hardwood lumber and to estimate the impact of changes in these factors.

B) To identify the major factors affecting wood furniture producers' demands for oak, maple, poplar, open grained and closed grained lumbers and to estimate the impact of changes in these factors.¹

C) To predict the levels of quantity supplied, quantity demanded,
price and inventories of hardwood lumber in the year 2005 under four
select scenarios.

Objective A was fulfilled by the specification and estimation of a
hardwood market model and six regional supply relationships. The market
model consisted of three equations representing aggregate supply, demand
and price relationships. Supply relationships for all hardwood lumber
and oak lumber were estimated for the Eastern, Northeastern and
Southeastern regions. The market model and the regional supply
relationships were estimated from secondary (published) data.

Objective B was accomplished by the specification and estimation of
equations representing furniture manufacturers' demands for oak, maple,
poplar, open grained and closed grain lumber. These equations were
estimated using survey data collected from furniture manufacturers.

Projections for future levels of quantity supplied, quantity
demanded and price of hardwood lumber were developed from a simulation
model. The simulation model was based on the structure of the market
model and parameter estimates the market model.

The estimated hardwood market model was recursive in nature with
the causal flow originating from the demand equation. It was
theoretically developed, and empirically supported, that demanders of
hardwood lumber are not able to react to changes in prices of lumber and
other inputs for one or two years after these changes have occurred.
However, lumber suppliers can react to changes in lumber price within a
year. Because of the relationship between lumber demanders and
suppliers, the structure of the hardwood market can be termed as a
reverse cobweb. The difference between this reverse cobweb structure and the traditional cobweb structure used for modeling many agricultural markets is that the traditional cobweb causal flow originates from the supply relationship. It was demonstrated that the stability conditions are the same for both cobweb structures, and that the estimated market model was stable.

One major implication obtained from the analysis of the market model was that a one percent change in wage rates has a greater impact on quantity demanded and supplied than a one percent change in output price, interest rate or stumpage price. When all repercussions have taken place, a one percent increase in wage rate causes a 1.14 percent decrease in quantity supplied, a 1.22 percent decrease in quantity demanded, and a .41 percent decrease in price. Hardwood lumber price decreases when wage rates increase because a change in wage rates affects quantity demanded more than it affects quantity supplied. An implication of these results is that lumber demanders and suppliers must address labor productivity problems in order to control costs.

Another variable which strongly influences the hardwood lumber market is the current price of the output of lumber demanders. A one percent increase in output prices causes quantity demanded to increase by .88 percent, quantity supply to increase by .93 percent, and lumber price to increase by 1.2 percent.

The rate of interest does not in itself drastically affect the production and usage of hardwood lumber. After all repercussions have taken place, a one percent increase in interest rate leads to a .17
percent decrease in quantity demanded, a .19 percent decrease in quantity supplied, and a .06 percent increase in price. However, it should be noted that higher interest rates indicate a higher rate of inflation. A higher rate of inflation usually increases production costs of hardwood lumber demanders and suppliers. Increased production costs may drastically reduce quantity of hardwood lumber demanded and supplied.

Price of stumpage affects the demand and supply of hardwood lumber, but has a greater affect on hardwood lumber price. A one percent increase in stumpage price leads to a .08 percent decrease in quantity of hardwood lumber supplied, a .28 percent decrease in quantity demanded and a .54 percent decrease in lumber price. An implication of these results is that increasing inventories and potentially decreasing price of hardwood sawtimber will not automatically result in increased hardwood lumber production. Rather, wage rates, labor productivity and output price will affect future production and usage of hardwood lumber to greater extent than stumpage price.

Although the short-run price flexibility of hardwood lumber export was near .15, the long-run affects of lumber exports on lumber price are much less because the increase in lumber price caused by exports will also cause supply of lumber to increase. After all ramifications have been taken into consideration, a one percent increase in hardwood lumber exports lead to a .03 percent increase in quantity supplied, a .04 percent decrease in quantity demanded and, a .04 percent increase in price of hardwood lumber. The implication of these results is the long0
run impact of lumber exports on price of hardwood lumber are one fourth the magnitude of the short run impacts.

The results of the three regional hardwood lumber supply equations indicate that quantity supplied adjusts faster in the Southeastern region than it does in the Northeastern region. Another result from this analysis was that suppliers in the Southeast tend to react to changes in input and output price to a greater degree than suppliers in the Northeast.

Wood furniture manufacturers' demands for hardwood lumber as a whole are not strongly dependent on the aggregate hardwood lumber price. However, these manufacturers' demands for lumber of specific species or groups of species are much more price responsive. Of the individual species and species groups, open grained, oak and maple lumber are more price responsive than poplar and closed grained lumber. The estimated results indicated that furniture manufacturers' demand for lumber of closed grained species are not greatly affected by price of closed grained lumber and lumber of other species, but are strongly influenced by the price of wood furniture. However, demand for oak and other lumber of open grained species are about equally affected by prices of open grained lumber, price of lumber of substitute species, and the price of furniture.

Maple lumber demand is different from the lumber demands for other closed grained species in that maple demand is very much affected by the price of maple lumber. Maple demand is similar to the demands for other closed grained species in that price of substitute lumber has little
affect on maple usage while the price of furniture seems to strongly affects the quantity of maple lumber demanded.

The estimated demand for poplar lumber indicated that quantity demanded of poplar lumber is affected only slightly by the price of poplar lumber but is greatly affected by the price of furniture. The negative cross price elasticity in the poplar demand equation indicates that poplar lumber is used in conjunction with lumber of other species, rather than being a substitute of lumber of other species. ²

Projections for the year 2005 indicate that the quantity of hardwood lumber demanded and supplied will continue at or near current levels if moderate inflation levels of the 1960's and mid 1970's occur in the future. Under the status quo scenario it was assumed that wage rates and price of lumber demanders output will increase at 3 percent per year, stumpage price increase at 2 percent per year and interest rate remaining at 8 percent. Under this scenario production and usage of hardwood lumber remained at or near 1970's levels while price of lumber increased at 5.4 percent per year.

Under the moderate inflation scenario, price of labor and output are assumed to increase at 5 percent per year, stumpage price is assumed to increase at 3 percent per year, while the prevailing interest rate was assumed to be 10 percent. Under this scenario, lumber production and usage decreased slightly relative to the status quo scenario while price of lumber increased at 7.4 percent per year.

Projections also indicate that if price of demanders output increases at a faster rate than price of labor, the quantity of hardwood
lumber produced and used will increase. This optimistic scenario assumed a 3 percent yearly increase in wage rates, a 5 percent per year increase in output price, a 2 percent yearly increase in stumpage cost, and a prevailing interest rate of 8 percent. Quantity of lumber produced and used rose 30 percent over current levels under the conditions of this scenario, while price of hardwood lumber increased at 8.0 percent per year.

Under the pessimistic scenario the inflation level of the early 1980's was assumed to continue over the next 25 years. Wage rates and price of output were assumed to increase at 10 percent per year, stumpage price was assumed to increase at 5 percent per year, and prevailing interest rate was assumed to be 16 percent. The results under these assumptions were a 50 percent decrease in lumber production and usage and an increase in lumber price of 12.1 percent per year.

CONCLUSIONS

Hardwood lumber production and usage has decreased during the 1970's relative the 1960's and 1950's. The price of hardwood lumber increased 96 percent between 1970 and 1978 as compared to a 15 percent increase from 1960 to 1969. Prices of One Common and Better oak, ash and other lumber of desirable species have increased up to 190 percent during the last 10 years. The questions that this study addresses are: (1) what are the factors which effect the hardwood lumber market and, (2) how have these factors contributed to the increasing price and the declining production and usage of hardwood lumber.
One alleged cause of increased hardwood lumber price is the increase in lumber exports. Exports increased by 300 percent from 1970 to 1978. But this increase in exports can at most account for 45 percent of the increase in price and probably accounts for only 30 to 40 percent of the price increase. Therefore, the large increase in lumber price can not be attributed only to the increase in lumber exports. However, the increase in export demand for oak, ash and possibly cherry lumber has probably had a significant influence on the large price increase in One Common and Better lumber of these species.

Hardwood lumber production remained at low levels during the 1970's even though hardwood lumber price increased by 96 percent. The cause of this apparent contradiction is that wage rates in saw mills increased by 125 percent and stumpage prices increased by 36 percent. This increase in wage rate had a depressing effect on hardwood lumber production since productivity of labor in saw milling remained constant from 1970 to 1978.

Hardwood lumber users have not only faced a 96 percent increase in price of hardwood lumber, but also had to contend with an 84 percent increase in wage rates. However, during the 1970's the price of hardwood users output increased only by 70 percent. This means production costs of lumber producers have increased at a faster rate than their revenues. Therefore, hardwood lumber users have reduced the level of output and the use of all inputs, including hardwood lumber.

Another important question raised in the problem statement of this study dealt with future availability of hardwood lumber. The answer is
that hardwood lumber will be available in sufficient quantities as long as there is a sufficient price to encourage production. It was earlier stated in this study that wage rates and labor productivity affect lumber production to a greater extent than stumpage cost. Furthermore, all projections developed in this study indicate future production levels are well within the bounds of current and future inventories of hardwood sawtimber. In fact, it is possible that a large amount of the current and future inventories of sawtimber will never be used for lumber production.

Current and future inventories of hardwood saw timber may be better utilized if fluctuations in the production, usage and price of hardwood lumber were reduced. A main source of these fluctuations is the reverse cobweb market structure. The problem associated with cobweb type markets and the fluctuating prices associated with these markets, is that seller and buyers are uncertain of future prices. In the hardwood lumber market uncertainty may discourage demanders from committing themselves to greater useage of hardwood lumber in the future. Lumber producers may also be discouraged from investing in expensive equipment and new technology. Furthermore, uncertainty may discourage future lumber demanders from committing themselves to using hardwood lumber and discourage new producers from entering the industry.

FUTURE RESEARCH

Methods of alleviating the problems associated with the cobweb market structure include forward contracting, vertical integration and
futures markets. However, development of an appropriate market coordination policy for the hardwood lumber market requires a separate study in itself and, therefore, is beyond the scope of the current study.

Another subject which merits future research is the development and implementation of labor saving devices for both lumber demander and suppliers. It was stated that the production and usage of hardwood lumber is more dependent on wage rate than on any other single factor. Therefore, labor productivity issues must be the subject of future research.

The effect of export of higher grade hardwood lumber on the price of lumber must be investigated by species. By undertaking this research, questions about the effect of exports on the price of some of the more desirable species of hardwood lumber can be better answered.
FOOTNOTES

1 Open grained lumbers include oak, ash, elm, pecan, hackberry and other wide grained lumbers. Closed grained lumbers include maple, cherry mahagony, beech, gum and other lumber with a tight grain structure.

2 It should be noted that the data base used in the estimation of the poplar demand equation did not contain data from any promotional furniture producers. Promotional furniture producers use poplar lumber in exterior parts and therefore may substitute poplar lumber for sweet gum, black gum or another inexpensive wood which can be embossed with a pattern.

3 Average yearly hardwood lumber production was 7056.4 thousand bf during the 1950's, 7030.3 thousand bf in the 1960's and 6745.3 thousand bf between 1970 and 1978. These averages were calculated from figures published in the Statistical Abstracts of the United States.

4 The price index of hardwood lumber (1967 = 100) increased from 90.8 in 1960 to 104.5 in 1969. This same index increased from 120.1 in 1970 to 236.0 in 1978. Source: Statistical Abstracts of the United States.

5 During the period 1970 to 1978 the price of One Common Appalachian red oak increased 153 percent, the price of One Common Appalachian tought ash increased 140 percent while the price of One Common Appalachian cherry increased 190 percent. Calculated from figures published in the Hardwood Market Report.

6 Exports of hardwood lumber have increased from 79 thousand bf in 1970 to 358 thousand bf in 1978. Calculated from United States Exports by Commodity by Country, Federal Trade Report 410.

7 As reported in this study the long term affect of exports on hardwood lumber price were much smaller in the long-run than in the short-run. If the short run price flexibility of .12 is multiplied by the percentage change in exports a 55 percent change in price is indicated. If the long-run multiplier of .04 is multiplied by the percentage change in exports a 14 percent change is indicated. Since exports have been steadily increasing during the 1970's both the short-term flexibility and the long-run multiplier are inappropriate in calculating the true affect of change in exports on price. Therefore, a middle figure of 30 to 40 percent is probably more appropriate than either 14 or 55 percent.

8 Since most increase in export lumber demand have been for higher higher grade oak and ash lumber, the dramatic increase in the prices of these lumbers over the price of all hardwood lumber has probably been caused by the increase in exports. There have also been reports of increased cherry lumber exports, however, no figures are collected for cherry lumber exports.
9 The wage rate at saw mills has increased from $2.71 per hour in 1970 to $6.10 per hour in 1978. Stumpage cost on National Forest land has increased from $30.20 per thousand board feet to $41.15 per thousand board feet between 1970 and 1978. Source Statistical Abstracts of the United States.

10 Output per man hour in saw milling was calculated at 4480 board feet in 1970 and 4393 board feet in 1978. Calculated from figures published in Employment and Earnings and Statistical Abstracts of the United States.


12 The weighted index of output price used in this study increased from 1.232 in 1970 to 2.107 in 1978. The index was calculated from figures published in Statistical Abstracts of the United States.


(10) Hair, D., Hardwood Market Outlook, 1977 John S. Wright Forest Congerence, Purdue University, Feburary 1977.


(17) McKillop, W. L., "Supply and Demand for Forest Products, an Econometric study", Hilgardia, University of California Agricultural Experimental Station, September 1967.


APPENDIX A

THE NERLOVIAN LAG

The Nerlovian approach was used in Chapter IV to incorporate dynamic adjustment into the supply and demand models. The purpose of this appendix is to review the development of this lag process and to show how it was incorporated into the equations. This section is a reiteration of concepts developed by Nerlove (23) as expressed by Havlicek (11).

DEVELOPMENT

Let $q^*$ be the quantity of an input demanded in a long run equilibrium, and let it be a function of the price of that input, the price of other inputs and the price of output. In the absence of changes in the prices of inputs and output, quantity demanded would change proportionally to the difference between the long run equilibrium and the current quantity demanded. This process could be expressed as the following difference equation.

$$A1) \quad q_t - q_{t-1} = \lambda(q^* - q_{t-1})$$

Where $\lambda$ is the constant of proportionality which can be considered as the coefficient of adjustment when quantity is expressed in natural logarithms. Let $P_i$ be the price of the input and $P_o$ be the price of the output. One representation of the long run demand curve is:
Where $a_1$ is the long run elasticity of input price and $a_2$ is the long run elasticity of output price. The error term was not included in equation A2 because it is not being viewed as a stochastic relationship. Rewriting A1, we see that:

A3) $Q^* = (Q_t - (1 - \lambda)Q_{t-1})/\lambda$

And substituting into A2:

A4) $(Q_t - (1 - \lambda)Q_{t-1})/\lambda = a_o + a_1P_{t} + a_2P_{o,t}$

or

A5 $Q_t = \lambda(a_o) + \lambda(a_1P_{t}) + \lambda(a_2P_{o,t}) + (1 - \lambda)Q_{t-1}$

or

A6) $Q_t = B_o + B_1P_{t} + B_2P_{o,t} + B_3Q_{t-1} + E_t$

where

$$B_o = \lambda(a_o)$$

$$B_1 = \lambda(a_1)$$

$$B_2 = \lambda(a_2)$$

$$B_3 = 1 - \lambda$$

hence

$$\lambda = 1 - B_3$$

If equation A6 was estimated by ordinary least squares the
resulting equation would be.

\[ A7) \quad Q_t = b_0 + b_1 P_{it} + b_2 P_{ot} + b_3 Q_{t-1} + e_t \]

Where \( b_0, b_1, b_2 \) and \( b_3 \) are the estimates of \( B_0, B_1, B_2 \) and \( B_3 \), respectively and \( e_t \) is the residual, for time period \( t \). The estimated elasticity of adjustment (\( \gamma \)) is found by:

\[ \gamma = 1 - b_3 \]

In equation A5 the \( a \) coefficients were long-run elasticities estimated if all variants have been transformed into logarithms. It is shown in equation A6 that these long run elasticities can be estimated by taking the short run elasticities, (or the \( B \) values), and dividing them by the elasticity of adjustment. Therefore, the long run elasticity estimates for input price for equation A7 is \( b_1 / \gamma \), and the long run elasticity for output price is \( b_2 / \gamma \).

NECESSARY CONDITIONS AND PROBLEMS

One condition, which is necessary in estimating a valid elasticity of adjustment in an input demand or output supply equation, is that demand and supply of the input do not react simultaneously. This condition is met in both the supply and demand equations estimated in Chapter IV, since demand and supply are determined independently or in a recursive system.
A drawback of the Nerlovian lag method is that the lagged dependent variable is not independent of the error term. This relationship causes the estimated coefficients to be biased downward. However, the degree of this bias is small in equations with a relatively small mean square error. Since all equations presented in Chapter IV had a relatively low mean square error the degree of bias in these equations is probably slight.

Another problem with the Nerlovian lag method is that it assumes that the same elasticity of adjustment is valid in the calculation of all long run elasticities. There are difficulties with this assumption if a producer can react faster to change in the price of one input versus the price of another input. Part of this problem can be alleviated by lagging some of the independent before estimated.
APPENDIX B

A STATISTICAL TEST FOR CORRELATION BETWEEN THE DISTURBANCE TERMS OF THE
AGGREGATE SUPPLY, DEMAND AND PRICE EQUATIONS

Previous studies of forest product markets by Mckillop (17), Adams and Blackwell (2), Manning (16), Adams and Haynes (1), and others assumed equilibrium systems with no inventories where supply, demand and price are simultaneously determined. This study assumed a recursive model of the hardwood lumber market. A test for the validity of this assumption is to determine if there is significant correlation between the disturbance terms of the various equations in the model. If the disturbance terms of the various equations are correlated, then simultaneity may exist, however if the disturbance terms are not significantly correlated then the hypothesis that the system is recursive can not be rejected.

A likelihood ratio test presented by Anderson (3) can be used to test the hypothesis that the disturbance terms of a system of equations are correlated against the null hypothesis that the disturbance terms are not correlated.

THE TEST

\[ H_0 \text{ the disturbance terms of the equations are not correlated} \]
\[ H_a \text{ the disturbance terms of the equations are correlated} \]

The test statistic is:

\[ -K \ln(W) \sim \chi^2, 1 - \alpha \text{ d.f.} \]

where:

\[ -121- \]
\[ K = (n + 1) - \frac{(2P + 11)}{6} \]

\( n \) = degrees of freedom for the system of equations

\( P \) = number of equations in the system

\( W \) = is the determinant of the correlation matrix of the disturbance terms across equations of the model

\( F = P \times \frac{(P - 1)}{2} \)

The correlation matrix of the disturbance terms of the equations contained in the market model is presented below:

<table>
<thead>
<tr>
<th></th>
<th>SUPPLY</th>
<th>DEMAND</th>
<th>PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUPPLY</td>
<td>1.00000000</td>
<td>0.27907001</td>
<td>0.00555151</td>
</tr>
<tr>
<td>DEMAND</td>
<td>0.27907001</td>
<td>1.00000000</td>
<td>0.02209228</td>
</tr>
<tr>
<td>PRICE</td>
<td>0.00555151</td>
<td>0.02209228</td>
<td>1.00000000</td>
</tr>
</tbody>
</table>

The system is composed of three equations and there was 35 degrees of freedom for the entire system of equations therefore:

\[ K = (35 + 1) - \frac{((2 \times 3) + 1)}{6} = 33.17 \]

\( W = 0.92164 \)

\[ F = 3 \times \frac{(3 - 1)}{2} = 3 \]

\[ -K \ln(W) = 2.71 \]

The critical value of \( \chi^2 \), with 3 degrees of freedom at the .05 percent level, is 7.81, therefore we can't accept the alternative hypothesis that the error terms are correlated at the .05 level of significance.
APPENDIX C

This appendix contains a copy of the Fortran program which was used in developing the net impacts of change in exogenous variables which were presented in Chapter IV. Documentation of the program is presented in the comment statements. The figures representing net changes in production, usage and price were calculated by running the basic program once and finding the values for quantity demanded, quantity supplied and price. A one percent change was made to one of the exogenous variables and the program was run again. The difference between the resulting value and the initial value was used in the calculation of the net effects.
//STEP1 EXEC FTG1CG,TIME=1,REGION=350K
//FORT.SYSIN DD*
C SET INITIAL VALUE FOR LAGGED QUANTITY DEMANDED (A), LAGGED INVENTORIES
C (RNLL), LAGGED AVERAGE HARDWOOD LUMBER PRICE (B), INDEX OF COMPOSIT OUTPUT
C PRICE (C), PRICE OF LABOR IN MANUFACTURING (D), INTEREST RATE (E), TIME
C (F), LAGGED QUANTITY SUPPLIED (G), CURRENT PRICE OF HARDWOOD LUMBER (H),
C LAGGED PRICE OF HARDWOOD LUMBER (PHLL), STUMPAGE PRICE (RJ), WAGES IN
C SAWMILLING (RK), CURRENT INVENTORIES (RN) AND EXPORTS (EX)

A=6668
RNLL=800
WRITE(6,3)
B=188
C=2.10
D=5.40
E=8
F=21
FS=21
G=6970
H=236
PHLL=5.298
RJ=45
RK=6.0
RL=E
RN=971
EX=350
CON=0
40 CONTINUE
CON=CON+1
C TRANSFORM ALL VARIENTS INTO NATURAL LOGARTHIMS
AL=ALOG(A)
BL=ALOG(B)
CL=ALOG(C)
DL=ALOG(D)
EL=ALOG(E)
FSL=ALOG(FS)
GL=ALOG(G)
HL=ALOG(H)
RJL=ALOG(RJ)
RKL=ALOG(RK)
RLL=ALOG(RL)
RNL=ALOG(RN)
EXL=ALOG(EX)
CON=CON+1
C CALCULATED QUANTITY DEMANDED BASED ON LAGGED INPUT PRICE AND CURRENT OUTPUT
C PRICE
QD=(AL*.19)-(BL*.96)+(CL*.56)-(DL*1.07)
K=-(EL*.104)+(FL*.35)+11.95
EQD=EXP(QD)
50 CONTINUE
C CALCULATE PRICE OF HARDWOOD LUMBER USING SET VALUE FOR QUANTITY DEMANDED
EP=EXP(P)

C CALCULATE QUANTITY SUPPLIED BASE ON PRICE VALUE DEVELOPED ABOVE
QS=(CL*.1)+(P*.67)-(RJL*.43)-(RKL*.76)
K-(RLL*.19)+(FSL*.39)+6.5
EQS=EXP(QS)

C TEST IF EQUILIBRIUM HOLDS, IF NOT INVENTORY IS ADJUSTED AND PRICE IS
C RECALCULATED UNTIL INVENTORY RESTRAINT HOLDS, NOTE QUANTITY DEMANDED,
C QUANTITY SUPPLIED AND INVENTORY ARE TRANFORMED OUT OF LOGARITHMS IN ORDER
C TO CHECK TO SEE IF EQUILIBRIUM HOLDS, THE NEW VALUE FOR INVENTORY IS THEN
C TRANFORMED INTO LOGARITHMS.
C
CINV=EQS-EQD+RNLL-EX
DIF=CINV-RN
RN=RN+(DIF/4)
80 CONTINUE
RNL=ALOG(RN)
IF (DIF.LT.1.AND.DIF.GT.-.1) GO TO 100
GO TO 50
100 CONTINUE
EPHLL=EXP(PHLL)
B=(EPHLL+EP)/2
IF (EPHLL.EQ.EP) GO TO 1000
PHLL=P
H=EP
A=EQD
RNLL=RN
G=EQS
GO TO 40
1000 CONTINUE
WRITE (6,1) CON,EQS,EQD,RN,EP
3 FORMAT(1X,6X,' CONT ',7X' SUPPLY ',6X,' DEMAND ',6X,' INVENTORIES'
K,4X,' PRICE ')
1 FORMAT(1X,2X,I4,10X,F9.2,7X,F9.2,9X,F8.2,7X,F7.2)
STOP
END
When estimating equations with ordinary least squares and pooled cross-sectional and time series data, the resulting parameter estimates are unbiased and consistent. However, these estimates may be inefficient because of the affects of auto correlation and heteroskedasticity. The Parks method is an Aitken's generalized least square procedure which incorporates prior information of the disturbance term in the estimation of the parameters. The resulting parameter estimates have the properties of consistency, unbiasedness, asymptotic efficiency and asymptotic normality.

The general form of the statistical model for pooled cross-sectional and time-series data can be expressed as:

\[ Y_{it} = B_0 + B_1 X_{it} + \ldots + B_K X_{it} + \nu_{it} \]

\[ (i = 1, \ldots, N) \quad (t = 1, \ldots, T) \]

The sample data are represented by T time-series and N cross-sectional observation for a total of \( N \times T \) observation. The statistical model can be expressed in matrix notation as follows:

\[ Y = XB + v \]

Where \( Y \) is a \( (N \times T) \times 1 \) vector of observations of the dependent variable, \( X \) is a \( (N \times T) \times (K + 1) \) matrix of observations of predetermined variables, \( B \) is a \( (k + 1) \times 1 \) vector of parameters and \( \nu \) is a \( (N \times T) \times 1 \) vector of disturbance terms. The ordinary least squares estimates for the model are:
Given the general model the following assumptions are made:

(i) \( E(v, v') = \Omega \), where

\[
\begin{bmatrix}
E(v_{11}^2) & \cdots & E(v_{11}v_{1T}) & \cdots & E(v_{11}v_{N1}) & \cdots & E(v_{11}v_{NT}) \\
E(v_{1T}v_{11}) & \cdots & E(v_{1T}^2) & \cdots & E(v_{1T}v_{N1}) & \cdots & E(v_{1T}v_{NT}) \\
E(v_{N1}v_{11}) & \cdots & E(v_{NT}v_{1T}) & \cdots & E(v_{N1}^2) & \cdots & E(v_{N1}v_{NT}) \\
E(v_{NT}v_{11}) & \cdots & E(v_{NT}v_{1T}) & \cdots & E(v_{NT}v_{N1}) & \cdots & E(v_{NT}^2)
\end{bmatrix}
\]

\((N \times T) \times (N \times T)\)

(ii) the predetermined variables are nonstochastic, and are independent of the disturbance term.

(iii) the number of observations exceeds the number of predetermined variables plus the intercept.

The specification of the behavior of the disturbance term for models estimated using time series data pooled cross-section and time series is:  

(i) \( E(v_{it}^2) = Z_{ii} \)

(ii) \( E(v_{it}v_{jt}) = Z_{ij} \)

(iii) \( v_{it} = p_i v_{i, t-1} + U_{it} \)

where:

\( U_{it} \sim N(0, o_{ii}) \)

\( E(v_{i, t-1} U_{jt}) = 0 \) for all \( i, j \)

\( E(U_{it}, U_{js}) = o_{ij} \) (\( i \neq j \))

\( E(U_{it}, U_{js}) = 0 \) (\( t \neq s \))

\( i, j = 1, \ldots, N \)
Condition (i) allows cross-sectional heteroskedasticity, condition (ii) allows mutual correlation of the disturbance term across cross-sections and, condition (iii) permits a separate first order autoregression scheme for each cross section. The autoregressive disturbance terms $U_{it}$, are assumed to be normally distributed with a constant variance and zero covariance between time period for the same cross-sectional unit (furniture firm). The autoregressive disturbances during the same time period are correlated across cross-sections, but the autoregressive disturbance for firm $i$, in period $t$, and firm $j$, in period $s$, for $s = t$ are assumed independent. Finally $v_{i, t-1}$ and $U_{jt}$ are assumed independent.

Given the specification of the behavior of the disturbance term, the following relationships can be developed:

(i) $E(v_{it}^2) = s_{ii}/(1-p_i^2)$

(ii) $E(v_{it}v_{jt}) = s_{ij}/(1-p_i p_j) = s_{ij}$

(iii) $E(v_{it}v_{is}) = p_i^{t-s} s_{ii}$ if $t$ greater than $s$

(iv) $E(v_{it}v_{js}) = p_i^{t-s} s_{ij}$ (i = j)

The initial disturbance term (v) associated with the pooled cross-sectional time-series data is assumed to have the following properties:

$v_{ia} \sim N(0, s_{ii}/(1-p_i^2))$

$E(v_{ia}v_{ja}) = s_{ij}/(1-p_i p_j)$
The matrix for the Parks model is:

\[
\Omega = \begin{bmatrix}
Z_{11}p_{11} & \cdots & Z_{1N}p_{1N} \\
\vdots & \ddots & \vdots \\
Z_{N1}p_{N1} & \cdots & Z_{NN}p_{NN}
\end{bmatrix}
\]

\[(N \times T) \times (N \times T)\]

where

\[
P_{ij} = \begin{bmatrix}
p_i & 1 & \cdots & p_j & \cdots & \cdots & p_j & \cdots & 1 \\
p_i & 1 & \cdots & p_j & \cdots & \cdots & p_j & \cdots & 1 \\
p_i & 1 & \cdots & p_j & \cdots & \cdots & p_j & \cdots & 1 \\
\vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
p_i & 1 & \cdots & p_j & \cdots & \cdots & p_j & \cdots & 1 \\
p_i & 1 & \cdots & p_j & \cdots & \cdots & p_j & \cdots & 1 \\
\vdots & \vdots & \ddots & \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\
p_i & 1 & \cdots & p_j & \cdots & \cdots & p_j & \cdots & 1 \\
p_i & 1 & \cdots & p_j & \cdots & \cdots & p_j & \cdots & 1
\end{bmatrix}
\]

\[(T \times T)\]

The Parks method estimates an \( \Omega \) matrix by first estimating a value for \( p_i \) from the an ordinary least square estimate. Using ordinary least squares the following equation is estimated

\[
D4) \quad Y_{it}^* = B_0^* + B_1^*X_{it}^* + \cdots + B_k^*X_{it}^* + U_{it}^*
\]

where

\[
Y_{it}^* = Y_{it} - p_iy_{i,t-1}
\]

\[
X_{it,k}^* = X_{it,k} - p_iX_{i,t-1,k} \quad (k = 1, \ldots, K)
\]

\[
B_0^* = B_0(1 - p_i)
\]

\[
U_{it}^* = v_{it} - p_iv_{i,t-1}
\]

\[t = 2, \ldots, T\]

\[i = 1, \ldots, N\]

From the residuals of the above estimation, \( U_{it}^* \) are calculated.
From these residual, estimates of \( \hat{o}_{ii}, \hat{o}_{ij}, \hat{Z}_{ii} \) and \( \hat{Z}_{ij} \) are obtained by:

\[
\hat{o}_{ii} = \frac{1}{T-K-1} \sum_{it} u_{it}^* \quad \hat{o}_{ij} = \frac{1}{T-K-1} \sum_{it} u_{it}^* u_{jr}^*
\]

\[
\hat{Z}_{ii} = \frac{o_{ii}}{1-p_i^2} \quad \hat{Z}_{ij} = \frac{o_{ij}}{1-p_ip_j}
\]

Using this procedure, consistent estimates of \( \hat{Z}_{ii} \) and \( \hat{Z}_{ij} \) are obtained, therefore, a consistent estimate of \( \hat{\Omega} \) is obtained. Finally using the Aitken's procedure,

D5) \( B = (X' \hat{\Omega}^{-1}X)^{-1} (X' \hat{\Omega}^{-1}y) \)

where \( \hat{\Omega} \) is a consistent estimator for \( \Omega \). The asymptotic variance-covariance matrix of \( B \) is

D6) \( \text{Var-Cov} \ (B) = (X' \hat{\Omega}^{-1}X)^{-1} \)
FOOTNOTES


APPENDIX E

This appendix contains a copy of the Fortran program which was used in developing the projects presented in Chapter VI. Documentation of the program is presented in the comment statements. The documentation is presented so as to allow others to develop their own projections based on alternative scenarios.
C SET INITIAL VALUE FOR LAGGED QUANTITY DEMANDED (A), LAGGED INVENTORIES C (RNLL), LAGGED AVERAGE HARDWOOD LUMBER PRICE (B), INDEX OF COMPOSIT OUTPUT C PRICE (C), PRICE OF LABOR IN MANUFACTURING (F), INTEREST RATE (E), TIME C (F), LAGGED QUANTITY SUPPLIED (G), CURRENT PRICE OF HARDWOOD LUMBER (H), C LAGGED PRICE OF HARDWOOD LUMBER (PHLL), STUMPAGE PRICE (RJ), WAGES IN C SAWMILLING (RK), CURRENT INVENTORIES (RN) AND EXPORTS (EX)

A=6668
RNLL=800
WRITE(6,3)
B=188
C=2.1067
D=5.41
E=10
F=21
FS=21
G=6970
H=236
PHLL=5.298
RJ=45.32
RK=6.10
RL=E
RN=971
EX=358
CON=0
YEAR=1978
40 CONTINUE
YEAR=YEAR+1
C TRANSFORM ALL VARIENTS INTO NATURAL LOGARITHMS
AL=ALOG(A)
BL=ALOG(B)
CL=ALOG(C)
DL=ALOG(D)
EL=ALOG(E)
FL=ALOG(F)
FSL=ALOG(FS)
GL=ALOG(G)
HL=ALOG(H)
RJL=ALOG(RJ)
RKL=ALOG(RK)
RLL=ALOG(RL)
RNL=ALOG(RN)
EXL=ALOG(EX)
CON=CON+1
IF (CON.GT.27) GO TO 1000
C CALCULATED QUANTITY DEMANDED BASED ON LAGGED INPUT PRICE AND CURRENT OUTPUT C PRICE
QD=(AL*.254)-(BL*.9382)+(CL*1.800)-(DL*1.303)
K=(EL*.096)+(FL*.346)+11.44
EOD=EXP(QD)
50 CONTINUE
C CALCULATE PRICE OF HARDWOOD LUMBER USING SET VALUE FOR QUANTITY DEMANDED
EP=EXP(P)
C CALCULATE QUANTITY SUPPLIED BASE ON PRICE VALUE DEVELOPED ABOVE
QS=(GL*.098)+(P*.67)-(RJL*.432)-(RKL*.763)
K=(RLL*.187)+(FSL*.392)+6.5
EQS=EXP(QS)
C TEST IF EQUILIBRIUM HOLDS, IF NOT INVENTORY IS ADJUSTED AND PRICE IS
C RECALCULATED UNTIL INVENTORY RESTRAINT HOLDS, NOTE QUANTITY DEMANDED,
C QUANTITY SUPPLIED AND INVENTORY ARE TRANFORMED OUT OF LOGRITHMS IN ORDER
C TO CHECK TO SEE IF EQUILIBRIUM HOLDS, THE NEW VALUE FOR INVENTORY IS THEN
C TRANFORMED INTO LOGARITHS.
    CINV=EQS-EQD+RNLL-EX
    DIF=CINV-RN
    80 CONTINUE
    RNL=ALOG(RN)
    IF (DIF.LT.15.AND.DIF.GT.-15) GO TO 100
    GO TO 50
100 WRITE(6,1)YEAR,EQS,EQD,RN,EP
C ALL VARIABLES ARE CALUCULATED TO THE NEXT YEARS VALUE
    EPHLL=EXP(PHLL)
    B=(EPHLL+EP)/2
    PHLL=P
    H=EP
    A=EQD
    C=C*1.05
    EX=EX*1.00
    D=D*1.03
    RNLL=RN
    E=E+0
    F=F*1.05
    FS=FS+1
    G=EQS
    RJ=RJ*1.02
    RK=RK*1.03
    RL=RL+0
    GO TO 40
3 FORMAT(1X,6X,' YEAR ',7X ' SUPPLY ',6X,' DEMAND ',6X,'INVENTORIES'
   K,4X,' PRICE ')
1 FORMAT(1X,8X,F5.0,7X,F9.2,5X,F9.2,6X,F8.2,7X,F7.2)
1000 CONTINUE
STOP
END
/*
APPENDIX F

This appendix contains the results of the four scenarios presented in Chapter VI. The assumptions for each scenario appears at the bottom of each table.
Table 14  PROJECTIONS UNDER SCENARIO NO. 1

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Assumptions under Scenario
1) Price of output increasing at 3% per year
2) Wage rates increasing at 3% per year
3) Stumpage price increasing at 2% per year
4) Prevailing interest rate 8%
5) Time trend variable increasing at one unit per year
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Assumptions under Scenario
1) Price of output increasing at 5% per year
2) Wage rates increasing at 3% per year
3) Stumpage price increasing at 2% per year
4) Prevailing interest rate 8%
5) Time trend variable increasing at one unit per year
Table 16 PROJECTIONS UNDER SCENARIO NO. 3

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2) Wage rates increasing at 5% per year
3) Stumpage price increasing at 3% per year
4) Prevailing interest rate 10%
5) Time trend variable increasing at 1.5 units per year
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**Assumptions under Scenario**

1) Price of output increasing at 10% per year
2) Wage rates increasing at 10% per year
3) Stumpage price increasing at 5% per year
4) Prevailing interest rate 16%
5) Time trend variable increasing at 2 units per year
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Historically, the quantity of hardwood lumber supplied and demanded has fluctuated from year to year while the price of hardwood lumber has trended with the wholesale price index. During the 1970's, production and usage of hardwood lumber trended downward while price increased by over 100 percent. The series of events which occurred during the 1970's, caused industrial users of hardwood lumber to express concern over current and future availability and price of higher grade lumber.

Currently, little economic information is available which can explain the behavior of the hardwood lumber market. Furthermore, the lack of such information inhibits the optimal allocation of capital, labor and other resources employed by producers and users of hardwood lumber. The general objective of this study was to provide economic information concerning the production, usage and price of hardwood lumber.

Three specific objectives were undertaken in this study: (1) To identify factors affecting hardwood lumber production usage and price, and to measure the impacts of changes in these factors; (2) To identify factors affecting wood furniture manufacturers' demands for hardwood lumber of various species, and to measure the impacts of changes in these factors; and (3) To predict future production, usage and price of
hardwood lumber under four different scenarios.

Major implications resulting from fulfillment of the first objective were that wage rates and price of output of lumber demanders are the most influential factors in the production and usage of hardwood lumber. Exports of domestically produced lumber were found to influence hardwood lumber price, however, the long-run affects of a change in exports is smaller than the short-run affects. The price of hardwood stumpage was also found to affect the production, usage and price of hardwood lumber; but, the magnitude which stumpage price affects the hardwood lumber market is small when compared to the affects of wage rates and output prices.

A major implication of the analysis of wood furniture manufacturers lumber demands was that these manufacturers have a very inelastic demand for lumber as a whole but, their demands for lumber of individual species are much more price elastic. Demand for open grained lumber such as oak and hickory appeared to be more price elastic than the demand for closed grained lumber such as cherry and mahogany. One exception to this rule was the demand for maple lumber which appears to be more price elastic than the demand for any other lumber.

Projections revealed little change in production and usage hardwood lumber relative to traditional levels, if the moderate inflation which existed during the mid 1960's and early 1970's is experienced over the next 25 years. Projections also indicate that lumber production and usage will decrease by 50 percent, if the high rate of inflation experienced in 1980 continues over the next 25 years.